Compendium

Promotion and Development of Industry 4.0 related skills

Strategic Partnerships for School Education

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Direction 4.0
Promotion and Development of Industry 4.0 related skills
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Smart Factories

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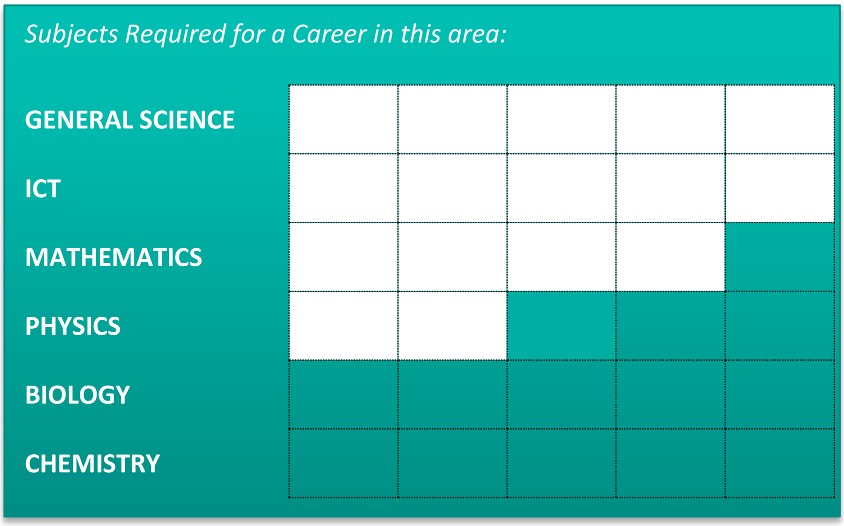
Many initiatives under the name Smart Factory has been increasing in recent years in Europe. Among the founders that catalyze these movements, announcing the beginning of the fourth industrial revolution, we find the publication of the German report "Recommendations for the Industry 4.0 Strategic Initiative".

However, how does the Smart Factory of this fourth industrial revolution take place? what is its impact on the European economy?

To answer these interrogations, this work addresses these issues by focusing on the different technological components that confer to these factories the smart features, as well as the technical characteristics directly related to their functioning, considered promising for the European economy.



Subjects Required for a Career in this area:

GENERAL SCIENCE	⬜	⬜	⬜	⬜	⬜
ICT	⬜	⬜	⬜	⬜	⬜
MATHEMATICS	⬜	⬜	⬜	⬜	🟩
PHYSICS	⬜	⬜	🟩	🟩	🟩
BIOLOGY	🟩	🟩	🟩	🟩	🟩
CHEMISTRY	🟩	🟩	🟩	🟩	🟩

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1 Introduction

European industry accounts for 23,8% of Europe's overall Gross Domestic Product (GDP) and is a key driver for innovation, productivity, growth and job creation. It employs more than 30 million people in Europe, and doubles it with support activities such as logistics. In addition, 80% of European exports are manufactured products [22].

However, Europe has been experiencing, for a number of years, an inexorable erosion of the position of its industrial base, with its global leadership position in a number of important sectors being challenged by emerging competitors. One of the main answers to this challenge lies in the development of the industry's technological excellence through the integration and development of new advanced technologies. These technologies relate, among others, to adaptive machines, information and communication technologies for manufacturing.

Driven by the emergence of these new technologies, Industry 4.0 is a new generation of factories incorporating these new technologies to bring to life an interconnected smart factory in which employees, machines and products interact with each other and also with their ecosystem (customers, suppliers, stock,). The term Industry 4.0 appeared for the first time in 2011 at the World Industry Forum in Hannover. It corresponds to a new way of imagining the means of production, which led to the appearance of the fourth industrial revolution. But before that, the industry had gone through several steps in its evolution.

2 Industrial Revolutions

From a historical point of view, it is quite possible to consider that the manufacturing activity began during prehistoric times. Indeed, to protect themselves against the external factors that threatened their survival (weather, wild animals, wild nature), men learned to act on this environment (control the fire, work the stone, the caves used as habitat…). The discovery of the fire and its mastery friction process has had a decisive impact in the evolution of the human species both socially and economically. Firstly used to cook, to protect against wild animals, and to light up at night, the fire was also used for matter transformation (metals in particular). All these activities are considered as the first signs of a human industry.

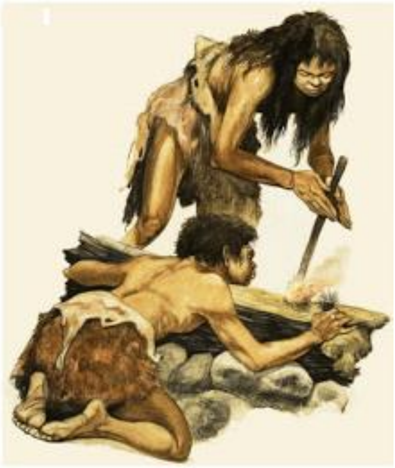

Image credits: ancient-history

Subsequently, it’s antiquity. This period is characterized by the appearance of pottery and the invention of the potter’s wheel, used for the creation of rounded ceramics. Also, the human uses the vegetable fiber for the preparation of clothing for protection against the cold weather and the wilderness of this period.

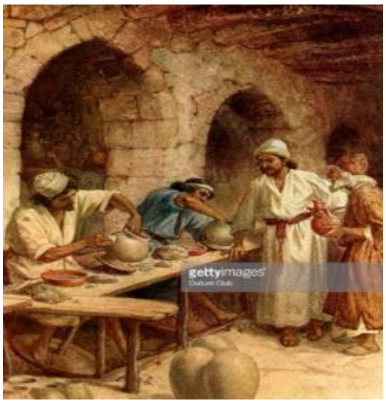

Image credits: Cultureclub

Then, generalization of use of the driving strength of the water mill, during the middle age period, to transform everything from grain to flour, and from walnuts to oil.

Image credits: Wikipedia

Afterward, it is the modern period, the era of the industrial revolutions. The first Industrial Revolution (XVIIIth Century) that can be called Industry 1.0 was the advent of motorized machinery. It goes back to coal mining and the development of the steam engine by James Watt in 1769. This will radically transform the way of manufacturing. Indeed, the craft industry will be replaced by mechanical production... In the factories, the revolution corresponds to the use of the steam engine as a motor to operate the machines allowing increased cadences. This leads to a larger production, and gives life to products in small series.

The Second Revolution is brought by the use of oil and electricity in the late XIXth century. This will help modernize the means of production. The automotive and chemical industries will benefit fully. From now on, production machines are no longer "steamed" but "electric". This period corresponds to the establishment of Taylorism and assembly line work making unskilled workers productive.

Then, a Third Industrial Revolution, called Industry 3.0, took place in the middle of the twentieth century with the advent of electronics, telecommunications or computer science. These different disciplines will easily set up important automations that relieve the workers of the most difficult tasks. This is the beginning of automation and mass production.

Industry 4.0 [12] [15] is the Fourth step of this industrial revolution, characterized by a fusion of Internet and factories. Each link in the supply chain, tools and workstations constantly communicates through the Internet and virtual networks. Machines, systems and products exchange information among themselves and with the outside. By optimizing the production facilities, manufacturers hope to produce faster, at lower cost and more environmentally.

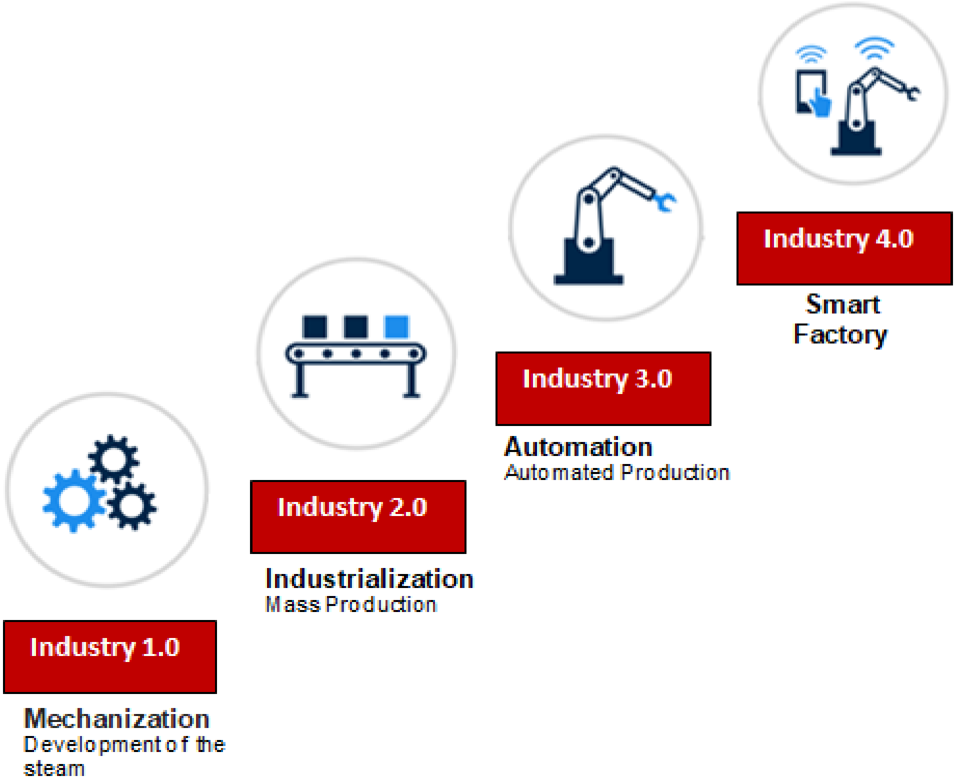

Figure 1. The Four Industrial Revolutions

Also known as smart factory, Industry 4.0 will equip themselves with intelligent machines, storage systems and facilities to exchange information autonomously, to control each other and to trigger independent actions. With Industry 4.0, fundamental improvements will be made to the engineering, manufacturing and supply chain processes. Manufacturing systems will be connected to corporate networks and outside world (their ecosystem).

3 Smart Factory: Characteristics

Smart Factory of Industry 4.0 is a technology approach that uses machines connected to Internet to monitor the manufacturing process. It integrates advanced technologies such as internet of things, robotics, 3D printing, virtual reality/augmented reality, big data and artificial intelligence. Its deployment requires the integration of smart sensors into machines in order to retrieve data on their operating status and performance.

Before to Industry 4.0, these data are saved in local databases, installed on the machines themselves, for example, used for maintenance in case of faults. Today, with smart factory, these data are saved in cloud, accessible anywhere, used by engineers to analyze them to detect the warning signs of a component failure of from all manufacturing system. To avoid unplanned downtime, a preventive maintenance intervention is launched.

These data are also used to identify the stages where manufacturing system is slowing down and to simulate different production scenarios, in order to determine the sufficiently efficient mode of operation.

With the spread of Smart Factory and the growth of the number of machines connected to the Internet of Things, the communication between machines will lead to more automation and robotization. For example, smart manufacturing systems could automatically control raw materials as stock declines, assign other machines to production to fulfill orders, and prepare distribution channels when orders are ready.

In the following, we give the main characteristics of smart factories (see Fig.2).

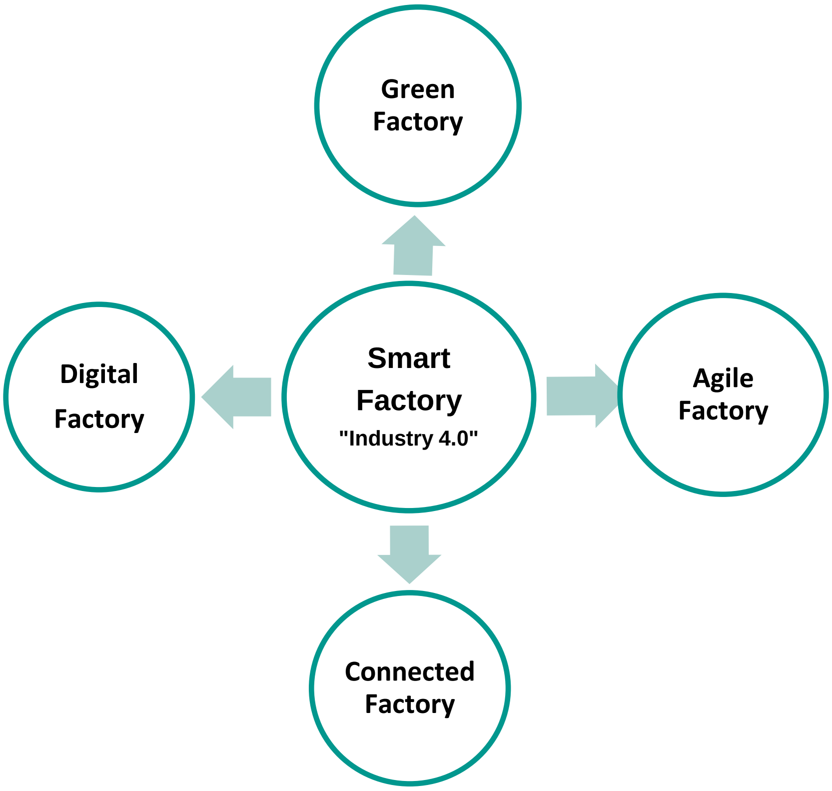

Figure 2. Characteristics of smart factory

3.1 Green Factory

Smart Factory of Industy 4.0 is ecological, it is defined as the creation of manufactured products that use non-polluting processes, conserve energy and natural resources (Multi-energy system: Photovoltaic, wind, ...). It industrializes its products by implementing modes of production with limited impact on the environment and the climate. This plant will be economical in energy and resources thanks to an instant and permanent network of communication and exchange with a coordination of needs and availabilities.

3.2 Connected Factory

In the Figure 3, are grouped functions of a connected factory, found essential and contributes to the understanding of the system. A smart cloud [18] is enforced by means of algorithms to perform: detection and prediction of critical conditions, verification and validation of configuration. The use of collaborative solutions can increase productivity by promoting teamwork, sharing of information and the organization. They offer a set of communication tools such as messaging, calendar, instant messaging, discussion forums, file sharing, etc.

Wireless Intelligent Network (WIN) is a concept being developed by the Telecommunications Industry Association (TIA) Standards Committee TR45.2. It is based on an open industry standard that enables equipment from different suppliers to interoperate successfully, and allows automatic roaming between various networks.

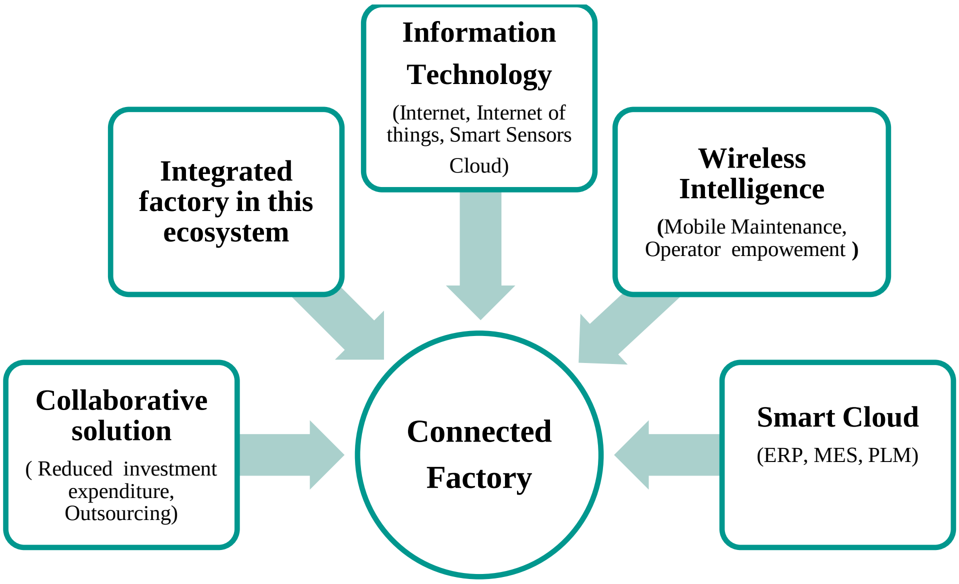

Figure 3. Main features of a connected factory

3.3 Agile Factory

An agile factory [8], is a factory able to repair itself for the adoption of the configuration according to operating constraints (customers, suppliers, environment, etc.). Unlike the flexibility which characterizes the ability of a physical system to move from a first known configuration (A) to a second known configuration (B), the agility characterizes the ability of a system to move from a first known configuration (A) to a second unknown configuration (B). The Agility requires the system to be smart and communicating (Internet of Things, cloud Manufacturing, Cybernetics ...). It concerns: technology; decision making; management of human resources; capital intensity and investment.

3.4 Digital Factory

The digital factory is the set of all digital tools allowing designing the process of manufacturing a product. It allows to validating the specification defined to manufacture a product by using 3D tools of simulation of the process, themselves coupled to the numerical model of the product.

4 Technological Components

Smart Factory (Industry 4.0) is characterized by a set of technological innovations (see Fig.4), allowing it to be competitive, efficient and permanently connected with employees, manufacturing machines, customers and its territory. It is based on the technological concepts of Cyber Physical Systems.

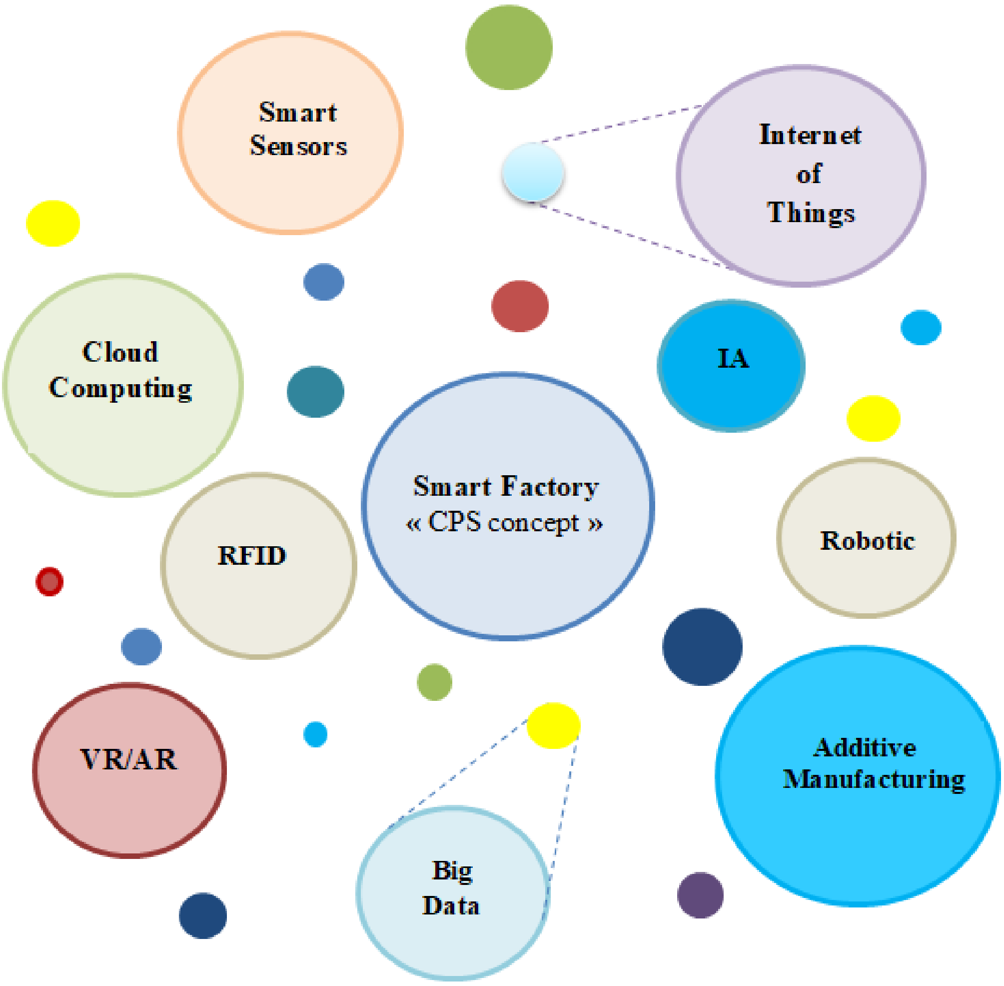

Figure 4. Technological components of a smart factory

- **Cyber Physical Systems (CPS).** According to [9], it is thanks to Helen Gill in 2006 at the National Science Foundation, that the term "Cyber Physical Systems" (CPS abbreviated) appeared. This concept indicates a new generation of systems with integrated computing and physical capabilities that can communicate with the outside world through many new modalities. Since then, these terms have become very popular and have been used to refer to systems such as smart sensors, embedded computers, actuators, etc., in order to achieve 'smart features" [5] and [17].

CPS are systems of collaborating computational entities which are in intensive connection with the surrounding physical world, providing and using, at the same time, data-accessing and data-processing services through Internet. In [9] the authors define a CPS as physical systems which operations are monitored, controlled, coordinated, and integrated by a computing.

In the Industrial context, the appellation of Cyber-Physical Production Systems (**CPPS**) is used relying on the latest and foreseeable further developments in Information and Communication Technologies (ICT) while Manufacturing Science and Technology (MST) are the pillars of the industry 4.0 [11].

The model depicted in Figure 5 [20] show that the Cyber-Physical Production Systems (CPPS) is composed of the physical manufacturing system that, through the existence of sensor-packed objects, it is actually linked to the Internet of Things. This way, the CPPS can share, use, process, or alter data as recommended by its powerful algorithms powered by Big Data analytics. These algorithms will be installed in cyber system part of the model depicted in Figure B, which is consists of four parts interacting.

- Physical System: It includes industrial processes, utilities and the source of production and energy storage.
- Interface: Includes the smart sensors [10] and actuators (used, as example, for the choice of a source of energy according to the instantaneous climatic conditions).
- Cyber system Part: To generate the controls of the manufacturing System and resources.
- Network communication: Bidirectional mobility data between cyber system and outside world through Internet.

- **Cloud Computing**. Cloud computing is an infrastructure in which computing power and storage are managed by remote servers to which users connect via Internet. It is already widely used for software and data management. In industrial field, where the interconnection of production workshops and different departments within the enterprise requires sharing large amounts of data, thanks to use of cloud this sharing of data became easy and fast.

- **Internet of Things (IoT)**. Embedded technology on machines to verify their state in real time, in order to analyze their behavior. With the presence of sensors on machines and objects in the manufacture process, the machines will be able to know the production history of product, the corresponding final demand in order to respond to it automatically or via a central control station.

- **Virtual Reality/Augmented Reality**. A direct use aims to provide immediately maintenance information on repair techniques of a room, for example via the wearing of augmented reality glasses. This technology can also be used to do training, or make design steps less abstract to involve more stakeholders.

- **Additive manufacturing**. This technology raises many hopes. Beyond the production of prototypes, additive manufacturing already allows the production in small series of complex parts, spare parts and even customized tools. With the maturation of technologies, the speed and accuracy of printing should increase and allow production on a large scale.

- **Robotics**. Industrial robotics is officially defined as an automatic control, reprogrammable, versatile manipulator programmable in three or more axes. Typical applications include welding, painting and assembly robots.

- **Smart sensors.** These sensors allow to have more performance, with real-time tracking and optimization, more agility with configuration changes and quick start-ups, more availability with predictive maintenance and remote diagnostics and more efficient, through the monitoring and control of system.

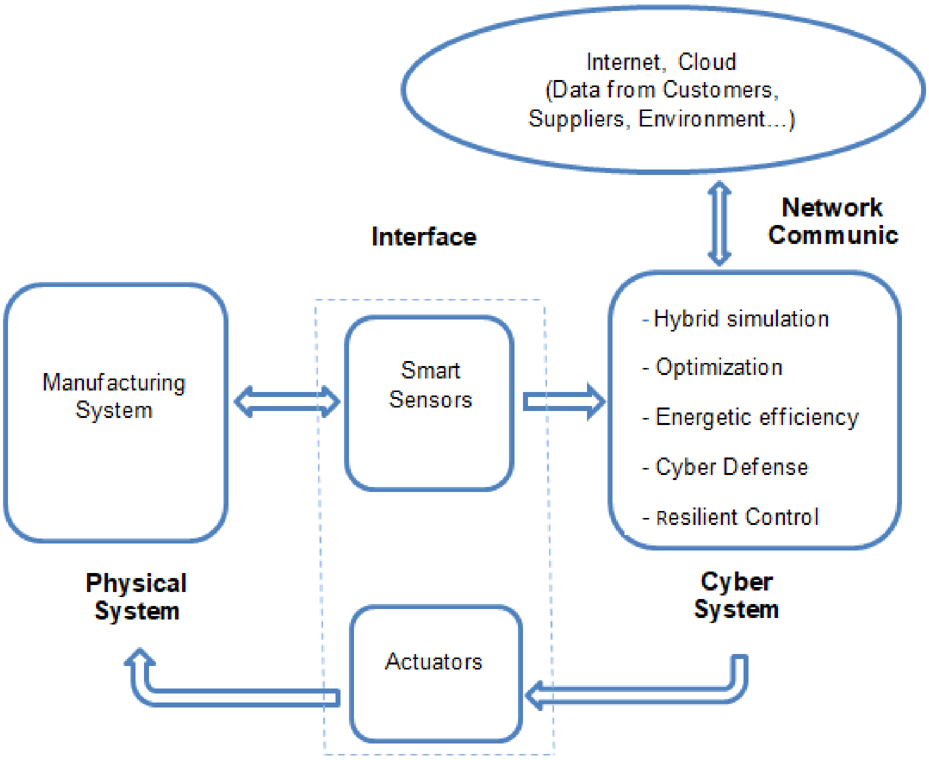

Figure 5. Model of Cyber Physical Production System

- **Big Data.** This is a concept for storing an unspeakable amount of information on a digital basis. According to the records of the Association for Computing Machinery (ACM) digital library in scientific articles about the technological challenges of visualizing "large data sets", this name appeared in October 1997.

- **Artificial intelligence.** Use of advanced algorithmic techniques, based on artificial intelligence, allowing exploiting large amounts of data. They optimize machine performance by implementing predictive maintenance and improve production quality through process control, by identifying correlations between multiple production parameters.

- **Radio Frequency IDentification (RFID)** is a method for remotely storing and retrieving data using markers known as "RFID transponder" or "RFID tags". They are small objects, such as self-adhesive labels, which can be incorporated into products. They include an antenna associated with an electronic chip that allows them to receive and respond to radio requests sent from the transceiver. These electronic chips contain an identifier and possibly additional data. In the smart factory, machines and objects communicate themselves: circuit RFID allows them to share important information with the systems of production. The smart factory controls itself and returns the much more effective production. The permanent exchange of the data in the smart factory facilitates the organization and the autonomy of supply chains.

5 Smart Factory in Europe

Smart Factory or "Industry 4.0" is one of the growing challenges in Europe, which must manage the transformation of an aging fleet. In this context, a form of competition is observed between different countries to accelerate the transition of the branch of industry to the model of the smart factory. Germany gave the kick-off in 2011; she was joined quickly by the main european economic powers, worried about preparing the future of their industry. The stakes differ according to countries, but, that it is a question of strengthening their leadership in the production of capital goods and manufacturing competitiveness.

For that, the technological projects of progress of the industry prosper almost everywhere in Europe. In the next, we present an overview of few promising initiatives.

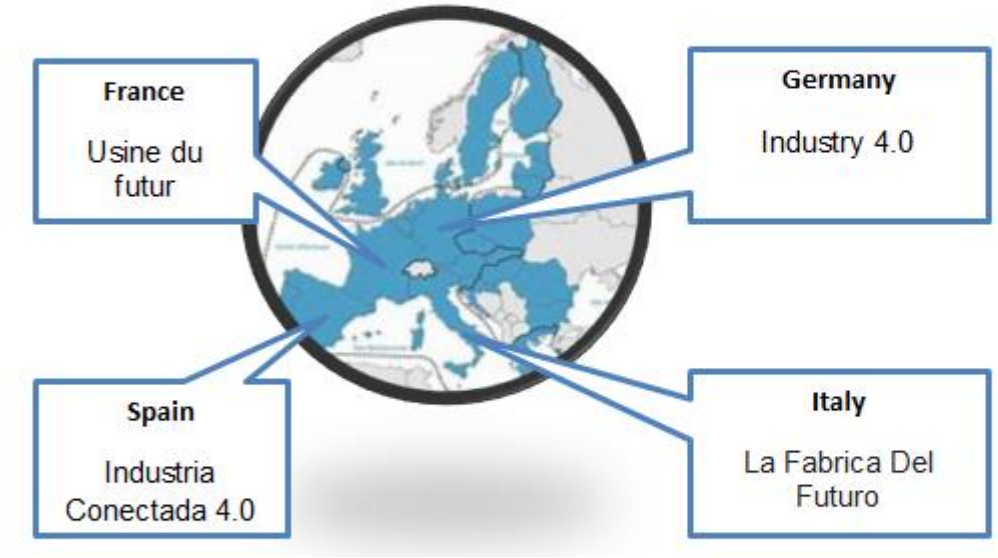

Figure 6. Smart Factory in Europe

- **Europe** (Factories of the Future) The initiative Factories of the future joins within the framework of the European plan of economic recovery. It is a Public Private Partnership which finances the development of applicable technologies in factories. Through the framework program (2007-2013) [21], 650 million € were given, then 1,15 billions € on the occasion of the launch of the program Horizon 2020.

- **Germany** (Industry 4.0) The German plan, thrown in 2012, echoes the road map on the embarked systems, an initiative which was taken in 2009 [26]. The government of Angela Merkel had wished to widen the works in all which concerns the production and the services. Piloted by Bosch and the Academy of Science and the Engineering (Acatech) [1][2], the plan pressed its reflections on the fourth industrial revolution, worth namely the arrival of the intelligence in the equipment of production. A report was handed in 2013. It contains, supporting examples, recommendations in eight domains: the standardization of the Industrial architectures; the management of complex systems; the broadband communications, the security of the data; the organization of the work; the work with the bodies of standardization; the efficiency of the resources; training and the personal development.

- **Italy** (La Fabrica Del Futuro) It is one of the four Progetti Bandiera; these big projects were thrown in 2012 by Italy and were endowed with 13 million € [24]. Planned for duration of three years, the initiative Fabrica Del Futuro supports the research to increase the competitiveness of the Italian industry. The Italian government wished that this program constitutes the link between Italian research and European research. A good effort of alignment: Fabrica Del Futuro shares all the objectives and the themes defined by the program Factories of the future of the European Commission. Ten Italian research projects are distributed in four categories: The high-performance factory, the evolutionary factory and reconfigurable, manufactures him for the man and the factory for a sustainable production.

- **France (Usine du futur)** The project "Industry of the future" was launched by the President of the Republic in 2015 [25]. It aims to modernize industries. The trades are going to be transformed: from the chief digital officer to the employees, who will be brought, not to intervene directly on the machines, but to control them. State of play of the evolution of traces.

- **Spain (Industria Conectada 4.0)** In 2014, the Spanish government announced the Connected Industry 4.0 project [23]. The objective of this project is to digitize and especially to the competitiveness of the Spanish industrial sector to become a strategy to support companies in the digital evolution. To consolidate its project, in 2017, the Spanish government has allocated 97.5 million € in innovative project loans and research for industrial companies, so that 68 million € (loans and direct aids) to companies in the ICT sector and 10 million € to an innovative pole.

The objective of the "Smart Factory" project: for each company to take a step on the path of the modernization of its industrial tool and the transformation of its economic model by digital. It is also about supporting companies in the transformation of their business models, their organizations, their modes of design and marketing, in a world where digital tools are breaking down the dividing line between industry and services. This fourth industrial revolution makes it possible to communicate the chains of production and the objects between them.

6 Economic and social impact of the Smart Factory in Europe

This digitization has modernized the industry and intelligent rendering has been followed by production. The data collected makes it possible to anticipate needs. In fact, it upset the way to produce and appear new trades. For examples:

- **Chief digital officer**, very popular in the industry. Its mission is strategic since it must accompany an industrial group to fully enter the digital age. After an inventory, it sets up an action plan by defining the numerical priorities for the company and the strategy.

- **Manager of the factory of the future** is the second business placed in the management. He is in charge, with a team of anticipating future developments: digital, big data, robotization, digital tools…. Accessing this position generally requires extensive experience in the industry and team leadership sector.

Finally, some trades are changing because of the arrival of smart sensors in the factories that follow and record the execution of operations in production, evaluate the wear of machines, anticipate future failures. It is mainly the maintenance trades that are concerned. The employees will be brought, not to intervene directly on the machines, but to control them. Their skills will evolve to know how to manage the data.

Beyond the gains, in terms of competitiveness, this revolution puts the human being at the center of the factory of the future. It contributes to a number of social and environmental developments that reinforce the meaning and acceptability of these developments for operators, consumers and the community as a whole.

- For operators, it can be synonymous with improving the quality of life at work, for example through the prevention of musculoskeletal disorders (MSDs) thanks, among other things, to numerical simulation that optimizes sizing of workstations. Similarly, flexible automation and the use of collaborative robots (cobots) eliminate strenuous tasks and unnecessary travel. Finally, the use of data transmitted by certain sensors is an increased safety vector at work, by actuating machinery stop mechanisms for example.

- For consumers, it offers a better level of security, thanks to improved quality and traceability of products (online control, accelerated adjustment in the event of a fault, use of the blockchain to trace the source of the components, etc.). It also allows consumers to better measure the impacts of product consumption (greater transparency, more information), leading to greater accountability and improved trust between the different parties.

- Finally, for the community, the smart factory makes it possible to reduce the environmental impact by, in particular, optimizing energy consumption and reducing waste.

7 Challenges of Smart Factory

All technological advances require strengthening the industry's ability to protect itself from the risks associated with the fraudulent use of data. The connectivity of equipment’s provides a significant attack surface for malicious individuals. Factories can be attacked from their computer systems. The main risk is the theft of manufacturing secrets, and even the shutdown of production lines. These attacks can be in different ways, for examples:

- **Attack by using the wireless networks** The production lines will be connected to the outside world through the wireless network. If not secure, an attack can occur from outside the factory and thus access manufacturing secrets or adversely affect the operation of the facility.

- **Attack of machine by USB key** The maintenance operator loads a new program into the Programmable Logic Control (PLC) of production line via its USB key. If the program is malicious, it is susceptible to damage or destroy the PLC.

- **Attack by using the business e-mail** an employee at company headquarters opens an e-mail and clicks on the infected attachment. It actually activates malicious code. Due to the connections between management production and computer network, the virus will spread and infect the industrial IT network.

- **Denial of service attack** A hacker identifies an unsecured internet access accessible from outside that leads to the industrial computer network of the factory. He chooses to flood the operator's control and supervision station with requests. It becomes inoperative. The factory can no longer control its production.

The cybersecurity will have to be preventive and take into account these multiple gateways for hackers. Indeed, the challenge will be to prevent intrusions into systems by being able to identify anomalies in the network in real time. Once inside the structure, the damage caused may be significant. Noting that no system is beyond the reach by cyber-attackers, and intelligent manufacturing systems are no exception. As Example of cyber-attack on a physical system, we can cite the cyber-attack using the "Stuxnet" virus. This latter, in early 2010, reportedly damaged approximately 1000 high-speed Iranian centrifuges used for enriching uranium [3][16]. Also, we can mention the piracy of Sony Pictures Entertainment [8] in November 2014, the violation of Yahoo data in 2016 [7], and the acquisition of information on private customers of Anthem Health Insurance in December 2014 [4]. In 2016, there was an attack on a power grid which cut power to over 100.000 peoples [16]. In the last decade, the industrial sector has been one of the most targeted sectors by cyber-attacks [13][14]. It has the highest number of security incidents reported to the Industrial Control Systems Cyber Emergency Response Team (ICS-CERT) in 2015 [19]. These attacks, use the Harpooning technique to gain unauthorized access to valuable information or trade secrets [6].

Beyond risk of cyber-attack, which represents the major challenge of the smart factory, there are other challenges awaiting this plant, which are summarized in the following table:

Smart Factory “Industry 4.0”	**Immediate Challenges**	• **Risks of cyber-attacks** • Opening up networks highlights problems • Take control of installation • Vandalism, Cyberwar • Enterprise and governments Not armed against these attacks.
	Global Challenges	• Uncertain geopolitical landscape • Increasing demand for energy • Instability of political governments • Complicated and complex regulations. • …
	Technological Challenges	• Maximum production at lower energy cost • Many technological locks will have to be lifted (Distributed Intelligence, Cloud, ...) • Technological disturbances (3D printing, Mobile computing…)

8 Conclusion

Intelligent, connected, efficient and economical, the Smart Factory constitutes a strong technological change of European industry. It is also a revolutionary economic concept devised by the German Chancellery to limit the effects of relocation of production, or even reverse it. 24 million new jobs in Europe are expected, thinks to the smart factory of Industry 4.0. We are at the beginning of this new era and many technological advances to be made (Distributed Intelligence, Cloud, ...).

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Augmented and Virtual Reality for Industry 4.0

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Industry 4.0 is the fourth step of the industrial revolution, characterized by a fusion of Internet and factories. Each link in the production chain and supply, tools and workstations constantly communicates through the Internet and virtual networks. Machines, systems and products exchange information among themselves and with the outside. Through the use of various technologies and by optimizing the production facilities, manufacturers hope to produce faster, at lower cost and more environmentally-friendly.

Two technologies which can be exploited by manufacturers in this fourth step of the industrial revolution are Augmented Reality (AR) and Virtual Reality (VR). With these technologies, designs can be tested virtually without the need of a physical prototype and manufacturing processes can be simulated and optimized, before the actual production process is run. The results are typically a shorter time-to-market and drastic cost savings.

Subjects Required for a Career in this area:

GENERAL SCIENCE	□	□	□	□	□
ICT	□	□	□	□	□
MATHEMATICS	□	□			
PHYSICS	□	□	□		
BIOLOGY					
CHEMISTRY					

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1 Introduction

Augmented Reality (AR) supplements the real world with virtual (computer-generated) objects that appear to coexist in the same space as the real world [1]. The interactive 3D image is superimposed on top of the regular field of view of the user to integrate the virtual world and the real world into one [2]. As described by Azuma et al. [3], [4], an AR system has the following characteristics:

- It combines real and virtual objects in a real environment;
- It aligns real and virtual objects with each other;
- It runs interactively, in three dimensions, and in real time.

Virtual Reality (VR) is the computer-generated simulation of a three-dimensional image or environment that can be interacted, in a seemingly physical way, with a person using special electronic equipment, such as a helmet [5]. In the virtual environment of a VR system, interactive control over the presented image is really important and gives the feeling of presence and of being part of a virtual scene, not from the position of an observer, but as a participant of virtual simulation. Interaction allows a user to control the virtual object and whole virtual scene in real time [6], [7].

Figure 1. AR (left) vs. VR (right)

The main difference between AR and VR is that, as opposed to VR systems, in which the user is separated from the real world and immersed in the virtual world, AR systems ensure free interaction with the real world, complement it and allow to enhance the human perception using interactive, virtual objects [8].

2 History of AR and VR

The first VR prototype was Sensorama, developed in 1960-1962 by Morton Heilig. Heilig created a multi-sensory simulator, in which a prerecorded film in color and stereo, was augmented by binaural sound, scent, wind and vibration experiences. This was the first approach to create a virtual reality system and it had all the features of such an environment, but it was not interactive [30]. Today VR has found numerous applications in different areas of science - it became a useful tool for architects, designers, physicists, chemists, doctors, surgeons etc. However, due to the high cost and fragility of equipment, up to the end of 1980, VR was hidden behind laboratory walls. It wasn't until the beginning of the 1990s, that a great interest of media dragged it to wide publicity.

Moreover, the development of cheap and powerful hardware allowed the spread of many installations opened to the public. The first were arcade games - computer games extended by an immersion feature using a head mounted display (HMD) and a tracking system. The great success of them forced the market appearance of further entertainment systems such as multi user car races, dungeon games, flight simulations and others [30].

With the help of see-through HMDs, it was discovered that additional information can be displayed to the user pointing his/her attention to important objects of the real world, for example, showing the way to a specified aim (e.g., by highlighting the right way through the city) or explaining the next step that must be performed to complete some task (from the complex ones like repairing complicated electronic devices or space shuttle elements in open space to easy ones such as operating faxes, laser-printers or changing a car tyre). This gave rise to AR (Augmented Reality) [30].

The first AR prototypes, which were created in the 1960s by computer graphics pioneer Ivan Sutherland and his students at Harvard University and the University of Utah, used a see-through to present 3D graphics (**Erreur ! Source du renvoi introuvable.**). Research continued during the 1970s and 1980s, when mobile devices like the Sony Walkman (1979), digital watches and personal digital organisers were introduced. This paved the way for wearable computing in the 1990s as personal computers became small enough to be worn at all times. Early palmtop computers include the Psion I (1984), the Apple Newton MessagePad (1993), and the Palm Pilot (1996). Today, many mobile platforms exist that may support AR, such as personal digital assistants (PDAs), tablet PCs, and mobile phones. It wasn't until the early 1990s that the term 'Augmented reality' was coined by Caudell and Mizell [9], scientists at Boeing Corporation who were developing an experimental AR system to help workers put together wiring harnesses [1].

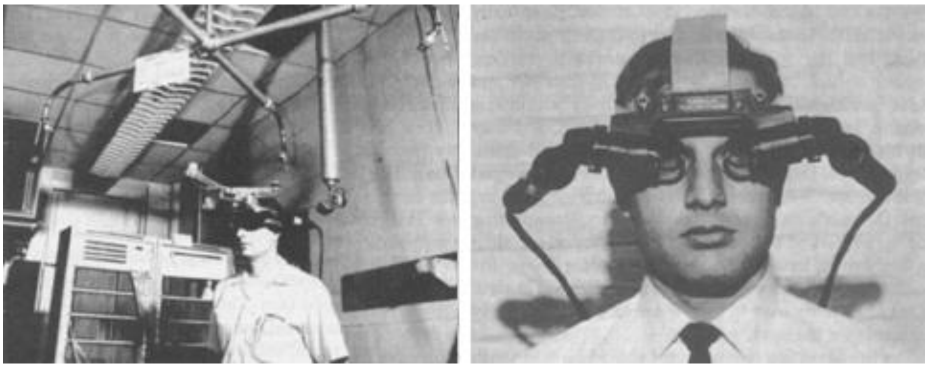

Figure 2. The first AR prototype [1]

3 Status of implementation and enabling technologies

The possibilities enabled with AR technology are endless - mechanics could see instructions what to do next when repairing an unknown piece of equipment, surgeons could see ultrasound scans of organs while performing surgery on them, firefighters could see building layouts to avoid otherwise invisible hazards, soldiers could see positions of enemy snipers spotted by unmanned reconnaissance aircraft, and we could read reviews for each restaurant in the street we're walking in, or battle 10-foot tall aliens on the way to work [1].

Figure 3. One example of the numerous applications of AR

Augmented reality it is not restricted to particular display technologies such as an HMD. Nor is the definition limited to the sense of sight, as AR can and potentially will apply to all senses, including hearing, touch, and smell. However, of all modalities in human sensory input - sight, sound and touch are currently the senses that AR systems commonly apply, whereas olfactory (smell) and gustatory (taste) displays are less developed [1].

There are two types of AR solutions – location-based and marker-based. Marker-based AR uses some type of image such as a 2D code to produce the result once the image is detected by a reader or camera (Figure 4). Location-based AR, on the other hand, is reliant on the capabilities of the device being used e.g. GPS locator, velocity meter (Figure 5).

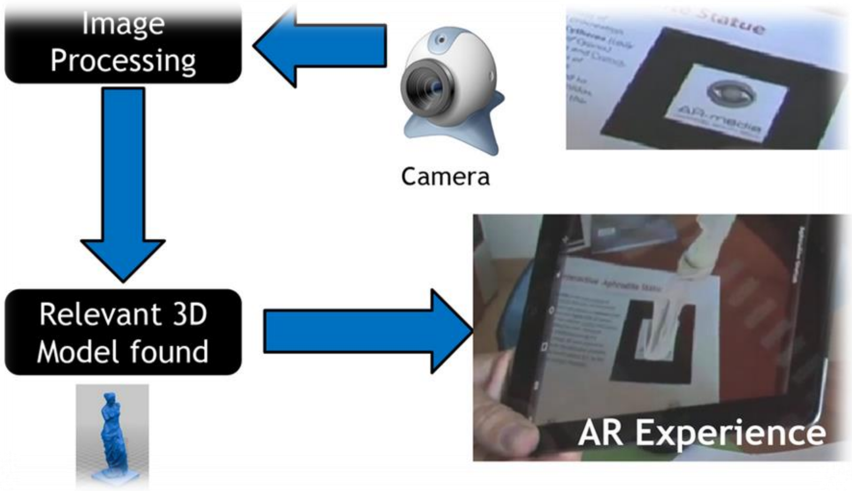

Figure 4. Marker-based AR

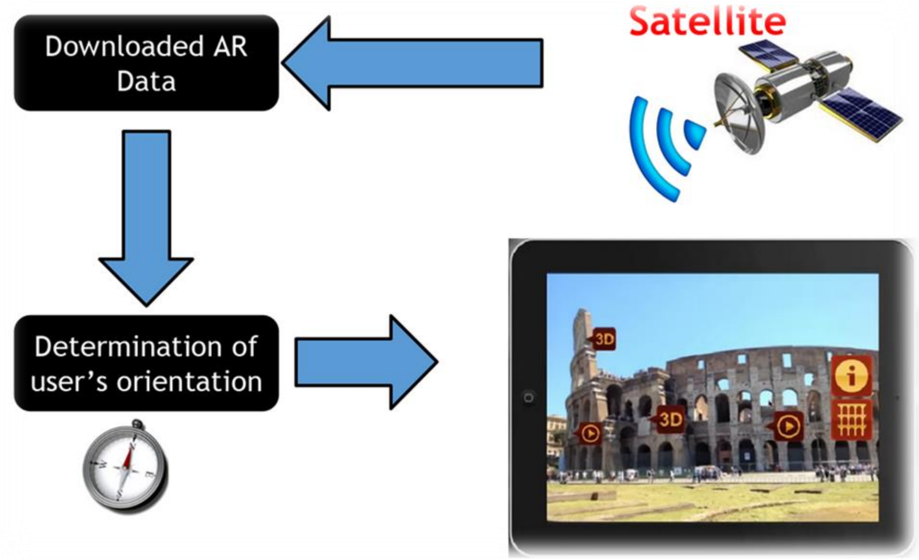

Figure 5. Location-based AR

In Virtual Reality systems, the main criterion of division is the level of immersion of the user in the virtual environment. The immersion is achieved mostly by stereoscopic projection, giving the user an illusion of spatial depth. The three main levels of immersion offered to the user are the following [30]:

- Desktop VR are sometimes called Window on World (WoW) systems. These are the simplest type of virtual reality applications. This level of immersion uses a conventional monitor to display the image (generally monoscopic) of the world. No other sensory output is supported.
- Fish Tank VR is an improved version of Desktop VR. These systems support head tracking and therefore improve the feeling of "of being there" thanks to the motion parallax effect. They still use a conventional monitor (very often with LCD shutter glasses for stereoscopic viewing) but generally do not support sensory output.
- Immersive systems are the ultimate version of VR systems. They let the user immerse totally in the computer-generated world with the help of an HMD that supports a stereoscopic view of the scene according to the user's position and orientation. These systems may be enhanced by audio, haptic and sensory interfaces.

Figure 6 depicts the most important parts of the human-computer-human interaction loop fundamental to every immersive system. The user is equipped with an HMD, tracker and optionally a manipulation device (e.g., three-dimensional mouse, data glove etc.). Head Mounted Displays work on the basis of two separate display screens put in front of the user's eyes, each supplied with a separate image, to make the user see a stereoscopic image. As the human performs actions like walking and head rotating (i.e. changing the point of view), data describing his/her behavior is fed to the computer from the input devices. The computer processes the information in real-time and generates appropriate feedback that is passed back to the user by means of output displays. Therefore, the user can move freely around and continuously see an image from the direction he is looking in – basically he is placed inside a virtual world which surrounds him completely [2]. In summary it can be stated that input devices in VR are responsible for interaction, output devices for the feeling of immersion and software for a proper control and synchronization of the whole environment [30].

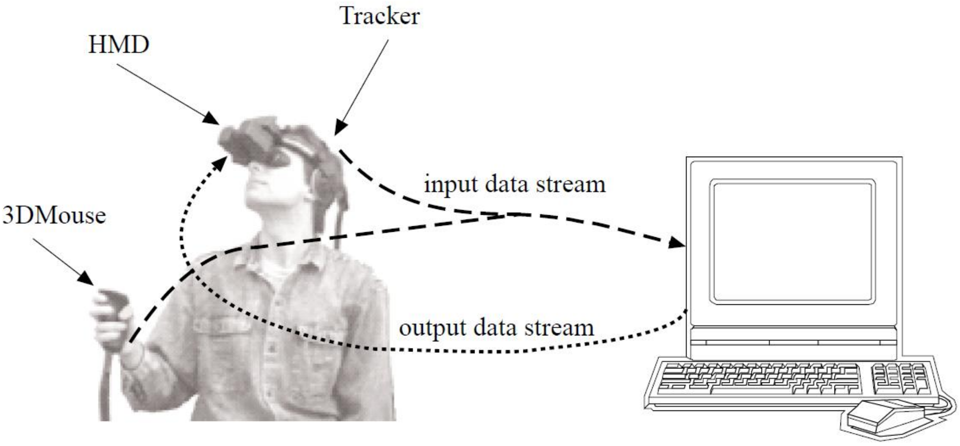

Figure 6. Basic components of a VR immersive

Another technology used for personal projection is the CAVE™ system, which offers total immersion via large projection screens. This system resembles a small room with large screens in place of walls. Basic systems have three walls, more advanced systems also have a roof and a floor. Rear projection is used to generate the image on all active walls. The user is surrounded by a three-dimensional image of the surroundings and is equipped with special glasses to help him see the stereoscopic image. The system requires at least three projectors to generate a fully synchronized image, sometimes cluster computing is required to achieve a smooth display in real time. An example of the CAVE projection is shown in the Figure 7 [2].

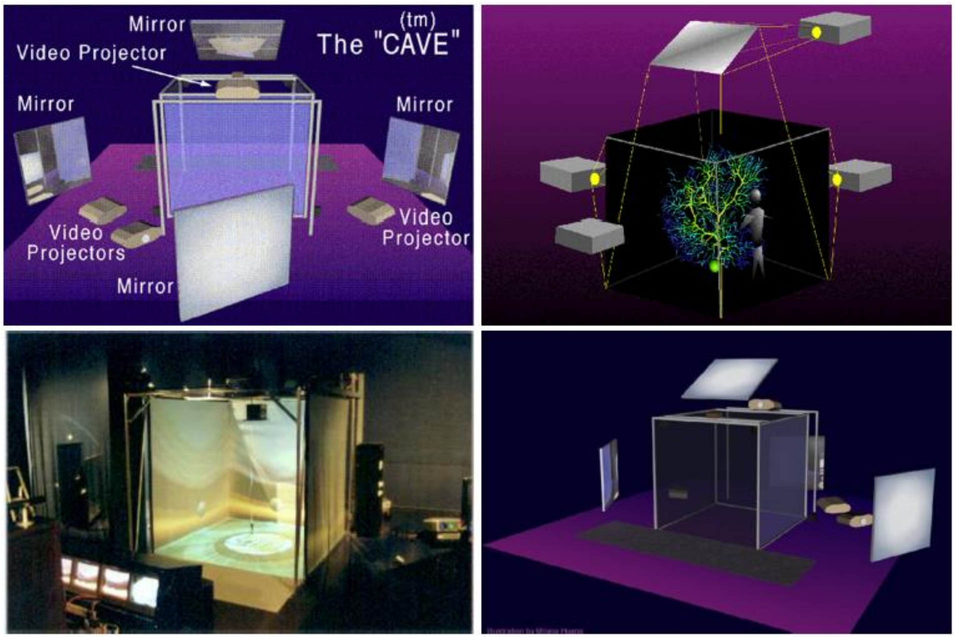

Figure 7. CAVE™ system principles

4 Use of AR and VR in Industrial applications

Virtual Reality is widely used in manufacturing, in fact the term “Virtual Manufacturing” (VM) was coined to describe the integration of VR and manufacturing technologies. VM is an integrated synthetic manufacturing environment used to enhance all levels of decision and control in a manufacturing system. The scope of VM can range from an integration of the design subfunctions (e.g. drafting, finite element analysis and prototyping) to the complete functions within a manufacturing enterprise, such as planning, operations and control [10]. For example, a virtual machining laboratory for machining skills training was implemented [11], in which both comprehensive knowledge learning and machining skills training can be achieved in an interactive synthetic environment. Using head-mounted stereo glasses and interactive gloves, students can virtually operate a lathe or set machining parameters and input a CNC G-code program to cut the workpiece automatically. Machining process performance, such as machining conditions, cutting forces, cutting power, surface roughness and tool life can also be simulated with the machining process evaluation models [10].

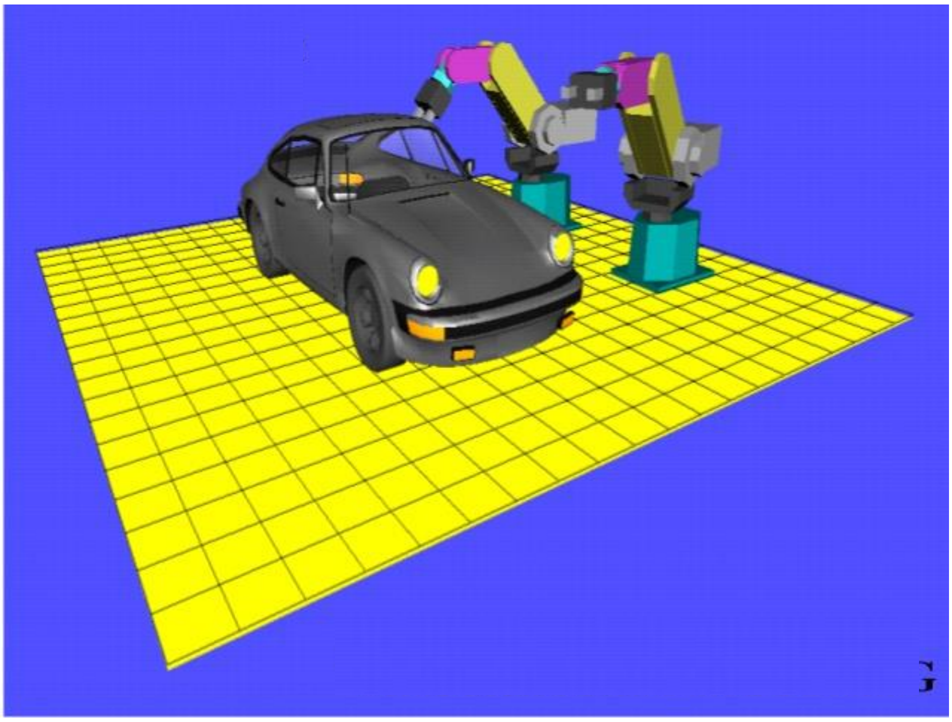

Figure 8. Virtual Manufacturing [12]

In addition, some commercial software for VM, such as Delmia’s VNC, can simulate machining processes in a 3D environment and detect collision [10]. By using a VM system, users can select and test different machining parameters to evaluate and optimize the machining processes. As a result, manufacturing cost and time-to-market can be reduced, leading to an improvement in productivity.

Similarly, as explained by Novak-Marcincin et al. [13], Augmented Reality can also support several areas of manufacturing, including AR aided robot control, AR aided testing and assembly and AR aided transport and storage. AR applications can also be employed to support the planning process on the shop floor [14]. These superimpose computer-generated information onto the real environment rather than replacing it as in the case of Virtual Reality (VR) [15].

Design, assembly, maintenance and planning are typical areas where AR may prove useful in industrial applications [1], as described in the sections below.

4.1 Applications AR in Industrial Design

Augmented Reality can be widely used in industrial design scenarios, for example to view and experience a new design without the need to actually fabricate a physical prototype. Fiorentino et al. [16] introduced the Space Design MR workspace that allows for instance visualisation and modification of car body curvature and engine layout (Figure **9**9). The MR Lab also used data from Daimler-Chrysler's cars to create Clear and Present Car, a simulation where one can open the door of a virtual concept car and experience the interior, dash board lay out and interface design for usability testing (Figure **9**9) [17], [18].

Figure 9. Left – SpaceDesign, Right - Clear and Present Car [17], [18]

4.2 Applications AR in Industrial Assembly

Pentenrieder et al. [19] show how Volkswagen uses AR in car assembly to analyse interfering edges, plan production lines and workshops, compare variance and verify parts. Boeing also use AR to overlay schematic diagrams and accompanying documentation directly onto wooden boards on which electrical wires are routed, bundled, and sleeved [20].

Figure 10. Augmented Reality used for industrial assembly [21]

4.3 Applications AR in Industrial Maintenance

Complex machinery or structures require a lot of skill from maintenance personnel and AR is proving useful in this area, for instance in providing “x-ray vision” or automatically probing the environment with extra sensors to direct the user’s attention to problem sites [1]. Friedrich [22] show the intention of having AR support electrical troubleshooting of vehicles at Ford and according to a MicroVision employee, Honda and Volvo ordered Nomad Expert Vision Technician systems to assist their technicians with vehicle history and repair information [23].

Figure 11. Augmented Reality used for service and repair [24]

4.4 Applications AR in Factory Planning

Before a manufacturing layout can be installed in a factory, layout designers must be confident that they have generated the best possible layout that supports the manufacturing process, optimises space and production, and guarantees a high maintainability and profitability [25]. Therefore, the planning result should be evaluated in view of the requirements of the manufacturing layout so that it can be validated. As part of an initiative to develop digital factory tools to support the factory planning activity, the research by Francalanza et al. [15], contributed to an AR factory planning approach framework, which is made up from a number of frames that support the factory planner to derive an AR model from an initial sketch. Through the use of this AR model, different stakeholders, such as machine operators, company management and process engineers, can visualize the factory plan. This can help the factory planner to make better decisions by modifying the layout according to the feedback received from all the stakeholders involved.

Figure 12: Augmented Reality used for factory planning [15]

5 Future directions of AR and VR in industry

Many engineers nowadays are able to design and test their projects (engines, aerodynamics of bodies or even whole mechanical constructions) with the help of VR. Testing a car, its road behavior, acceleration and other properties is a fascinating and cheap alternative to traditional design processes that very often last for years [30].

In the field of AR, from early research in the 1960's until widespread availability by the 2010's there has been steady progress towards the goal of being able to seamlessly combine real and virtual worlds [31]. By 2020, Feiner [26] envisaged that "augmented reality will have a more profound effect on the way in which we develop and interact with future computers." With the advent of such complementary technologies as tactile networks, artificial intelligence, cybernetics, and (non-invasive) brain-computer interfaces, AR might soon pave the way for ubiquitous (anytime-anywhere) computing [27] of a more natural kind [28] or even human-machine symbiosis as Licklider [29] already envisioned in the 1950's.

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Cloud Computing

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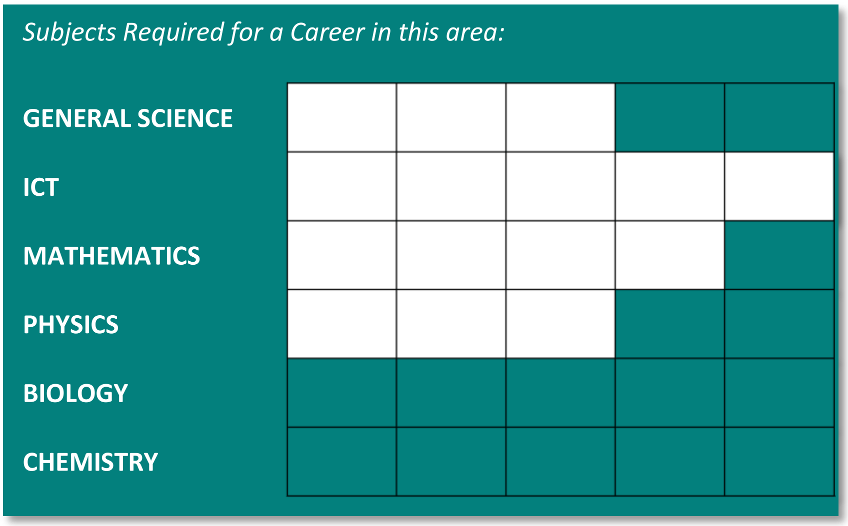
In cloud computing, large pools of computer systems share an IT infrastructure, enabling products, services, and solutions to be accessed and consumed in real-time over the Internet, typically through a subscription. It is one of today’s technology trends because it can reduce costs and simplify processes. Having different models and offering a wide range of services, cloud solutions can satisfy any need, either if is just storing of data or even deploy new products in to the market. All can be done through the right cloud-based service. Companies are shifting their efforts in how to correctly utilize the Cloud to achieve their business goals. Cloud computing is one of the key technologies for Industry 4.0 and has provided Big Data with a way to store, retrieve and analyze an immense amount of information. With more and more organizations adopting cloud computing, the market grows significantly each year, creating value to the economy, job opportunities, and new skills and businesses.



Subjects Required for a Career in this area:

GENERAL SCIENCE	⬜	⬜	⬜	🟩	🟩
ICT	⬜	⬜	⬜	⬜	⬜
MATHEMATICS	⬜	⬜	⬜	⬜	🟩
PHYSICS	⬜	⬜	⬜	🟩	🟩
BIOLOGY	🟩	🟩	🟩	🟩	🟩
CHEMISTRY	🟩	🟩	🟩	🟩	🟩

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1 Introduction

Cloud computing has been introduced as the next generation of on-demand services over the Internet. This new and emerging technology utilizes the concepts of connectivity, processing power, virtualization and storage resources, and share them over the Internet [1]. Cloud-based services are used more and more in various industries and environments, increasing the efficiency in accessing shared pools of configurable computing resources. This rapid growth of use is due to the considerable advantages of storing and maintaining computing resources in unlimited storages with the most cost efficient method, scalability and business continuity [2].

However, there are some significant concerns for service providers and end-users of this powerful, modern technology that have to do with the facts of security and privacy. These two concerns are the most challenging issues in cloud computing and have become the cause of impeding its development and decreasing its reliability [3].

1.1 Definition

According to the National Institute of Standards and Technology (NIST), cloud computing is defined as “a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing services (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction” [4]. This definition by NIST is considered the most acceptable by the research community.

In other words, cloud computing is “a large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust a variable load allowing also for optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model” [5].

1.2 Characteristics

NIST [4] presents five characteristics of cloud computing:

1. *On-demand self-service*: Non-required human interaction with each service provider when a user wants to use cloud services.
2. *Broad network access*: Capabilities are available anytime over the network and accessed anywhere by different means (e.g., mobile phones, tablets, laptops, workstations)
3. *Resource pooling*: Provider’s computing resources are pooled to serve multiple customers using a multi-tenant model, with different physical and virtual resources that are assigned dynamically based on the demand.
4. *Rapid elasticity*: Rapid outward and inward scaling of cloud capabilities that are elastically provisioned and released according to the demand.
5. *Measured service*: Resource usage is monitored, controlled and reported, providing transparency for both the customer and the provider.

1.3 Architecture of cloud computing

The architecture of a cloud computing environment consists of 4 layers: the hardware/datacenter layer, the infrastructure layer, the platform layer and the application layer [6]. A fifth layer is added in cloud computing architecture according to [3], the network layer. Figure 1 illustrates the different architectural layers of cloud computing.

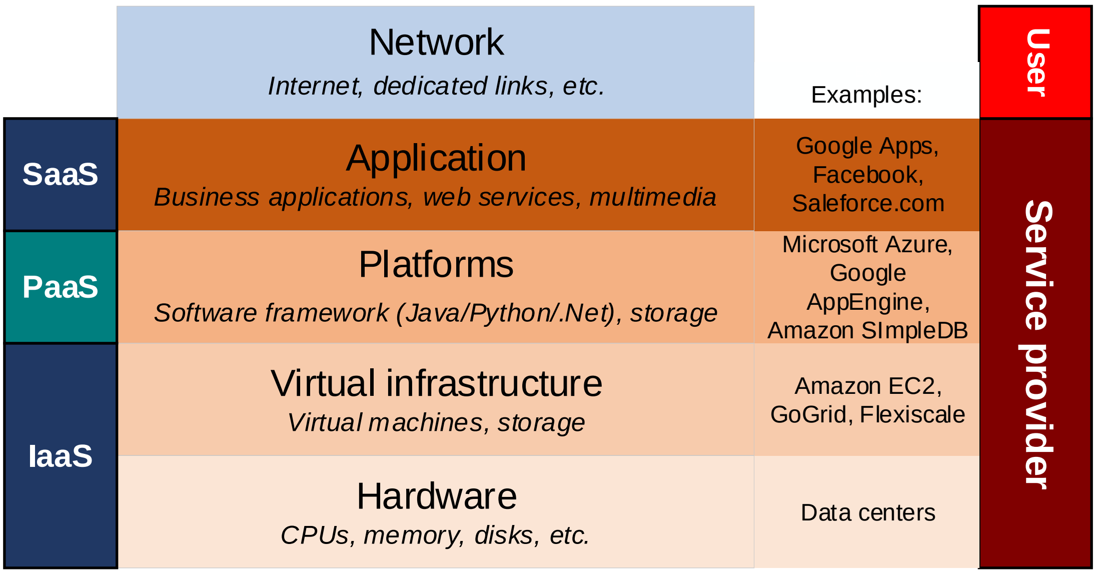

Figure 1 Cloud computing architecture, adapted from [3] and [6] .

- The hardware layer

The hardware layer is typically implemented in data centers. It is responsible for managing the physical resources of the cloud. These include servers, routers, switches, power and cooling systems. A data center usually contains thousands of servers that are organized in racks and interconnected through switches, routers and other fabrics [6].

- The infrastructure layer

The infrastructure layer, also known as the virtualization layer, creates a pool of storage and computing resources by dividing the physical resources using virtualization technology and creating virtual machines (VM). Many key features of cloud computing, such as dynamic resource assignment, are made available through virtualization technologies, hence the importance of this layer [6].

- The platform layer

The platform layer consists of operating systems and application frameworks. This layer has the sole purpose of minimizing the burden of deploying applications directly into VM containers. For example, an application framework provides support for implementing storage, database and business logic of typical web applications [6].

- The application layer

The application layer consists of the actual cloud applications. Cloud applications can leverage the automatic-scaling feature of cloud computing to achieve better performance, higher availability and lower operating cost [6].

- The network layer

The network layer belongs to the front-end side of the cloud and involves the means the customer uses to access and benefit from the cloud computing technologies (e.g., the Internet) [3].

1.3.1 Service models

Cloud offers services that can be categorized into three categories: infrastructure as a service (IaaS), platform as a service (PaaS), and software as a service (SaaS) [6]:

1. *Infrastructure as a Service*: IaaS refers to on-demand provisioning of infrastructural resources, in terms of VMs. The cloud owner who offers IaaS is called IaaS provider. Examples of IaaS providers include Amazon EC2 [7], GoGrid [8], and Flexiscale [9].
2. *Platform as a Service*: PaaS refers to providing resources in the platform layer, including operating system support and software development frameworks. Examples of PaaS providers are Google App Engine [10], Microsoft Azure [11], and Force.com [12].
3. *Software as a Service*: SaaS refers to providing on-demand applications over the Internet. Examples of SaaS providers are Salesforce.com [11], Rackspace [13], and SAP Business ByDesign [14].

Figure 2 shows the business model of cloud computing as resulting by the different services, explained above.

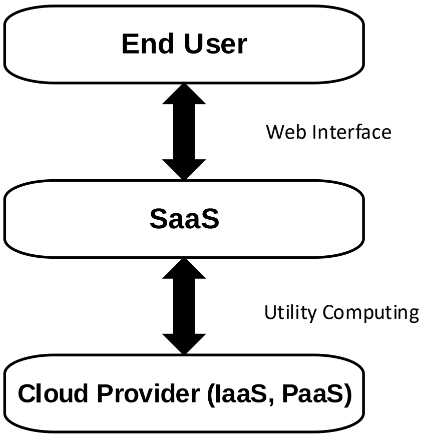

Figure 2 Cloud computing business model, adapted from Zhang et al. (2010) [6]

1.3.2 Cloud types

There are four different types of clouds, each with its own benefits and drawbacks. The reasons of having different types, stems from the many issues to be considered when an enterprise, for example, wants to move an application to the cloud environment. Some enterprises are interested in decreasing operation cost while others prefer high reliability and security [6]. Hence the four cloud types:

1. Public clouds: A cloud service that is accessible to be used by the general public. Although it is considered to be the lowest cost option for cloud providers and users, it lacks security and data control [3] [6].
2. Private clouds: A cloud service designed for the sole use of a single organization. A private cloud can be built and managed by the organization or external providers, and offers the highest degree of control over performance, security and reliability [3] [6].
3. Hybrid clouds: A cloud service that combines characteristics from both public and private clouds. It uses integrated hosting environments with different levels of security and privacy for sharing IT resources between the subscribers. In a hybrid cloud, part of the service infrastructure runs in private clouds while the rest runs in public clouds. It is also considered to increase efficiency by optimizing resources between private and public clouds [3] [6].

4. Virtual Private Cloud (VPC) / Community Cloud: A VPC runs on top of public clouds and is a solution to address limitations of both private and public clouds. By leveraging virtual private network (VPN) technology, it enables the service providers to set security rules according to their needs. It is also considered to be a “cheap” and easy solution for companies that consider turning to a cloud-based infrastructure [3] [6].

1.4 Advantages of cloud computing

According to [15], the benefits of cloud computing mainly include low-cost, availability on network, innovation power, high expandability, and friendly utilizations. Cloud computing is a cost-effective solution for data-intensive applications. Moreover, one of the basic characteristics of cloud computing – virtual machine – benefits both clouds providers and users. A VM is able to make an illusion of running directly on the physical machine, and it can be beneficial for isolation and resource sharing between multiple operating systems. In storage-as-service, for example, clouds users can freely use cloud resources with planning to scale-up or scale-down; clouds providers also can maximize the performance of their servers and resources [15]. Moreover, [16] presents some more advantages of cloud computing:

1. *Easy management:* The maintenance of the infrastructure, be it hardware or software is simplified, thus, less work for the IT department. Also, applications that are quite storage extensive are easier to use in the cloud environment. Finally, at the user level, all is needed is a web browser with internet connection.
2. *Cost reduction:* The main advantage for SMEs lies here. Cloud computing drastically reduces the IT spending for SMEs. Costly systems are not required for occasional use of intensive computing resources.
3. *Uninterrupted services:* Lower outages are provided by cloud computing services, thus providing uninterrupted services to the user.
4. *Disaster management:* In case of disasters, an offsite backup is always helpful. Keeping crucial data backed up using cloud storage services is what every organization wants or should want. Also cloud storage services not only keep the users’ data off site; they also ensure that they have systems in place for disaster recovery.
5. *Green computing:* Harmful emissions due to extensive use of systems in organizations, electronic waste generated as the time passes and energy consumption is the main disadvantage of the present-day computing systems. This can be reduced to some extent by using cloud computing services and generate e-waste to minimum extent.

1.5 Challenges of cloud computing

There are several challenges for cloud computing to surpass. This section presents a list of the most important challenges as defined by [17].

1. *Security problems*: Security problems involve data security of individual and organization data, system reliability in terms of connection problems to the Internet (connections loss, speed, etc.), policy specifications since there is no unified market specifications and legal constraints, and privacy protection of information the users store in the cloud storage.
2. *Competition problems*: Cloud computing has the impact on the traditional hardware and software manufacturers. Cloud computing services were once bought by many users, however there is a declining interest the last years. Moreover, there is competition between providers that affects the users, meaning that for a user or

organization will not be easy to subscribe to a new provider and having to move all the data and resources.

3. *Government problems*: Cloud computing benefits are noticed by governments that want to use the services, but security risks have not made it easy for governments to share important and classified data to cloud providers.
4. *Education problems*: Since cloud computing is an emerging technology, a lot of new competencies are required, and schools and universities should reconsider the curriculums in their computer, IT and engineering programs.

1.6 Cloud computing and Industry 4.0

Industry 4.0 is a complex and flexible system involving digital manufacturing technology, network communication technology, computer technology, automation technology and many other areas. On the one hand, the basis of its implementation is based on digital design and simulation, highly automated manufacturing processes, production data management networking and, production process management, converting the whole process to access of knowledge and the laws of management, mining, analysis, judgment and decision-making. On the other hand, Industry 4.0 is based on cyber physical systems, which use computing, communications and control technologies in tight collaboration to achieve real-time sensing intelligent production systems, dynamic control, and information services [18].

Within the key technologies of Industry 4.0 is cloud computing, which helps realizing the concepts of the 4th industrial revolution. Cloud computing offers low cost and high-performance services that can be utilized to store and easily share the big amounts of generated data from production machines and other devices in an industry.

1.6.1 Cloud manufacturing

Cloud manufacturing stems from cloud computing technologies and Industry 4.0 concepts of digital manufacturing and information technology. Cloud manufacturing can be defined as an intelligent and collaborative manufacturing service-model [19].

Distributed manufacturing resources (e.g. machine tools, 3D printers, computer-aided design/manufacturing/engineering/process planning software, models' repository, databases, etc.), and manufacturing capabilities (e.g. design capability, fabrication capability, assembling capability, simulation capability, testing capability, etc.) are interconnected and form a shared pool in the cloud manufacturing platform. In cloud manufacturing, customers, providers and platform managers all win what they want by running manufacturing service businesses.

Therefore, a *cloud manufacturing platform* or *cloud platform* is an entity that manages a shared pool of manufacturing resources and capabilities over a network, offering integrated IT-based infrastructures and tools for both suppliers and demanders to release and to utilize cloud services on demand, respectively [19].

2 State of implementation of cloud computing

Cloud computing spending is growing at 4.5 times the rate of IT spending since 2009 and is expected to grow at better than 6 times the rate of IT spending till 2020. According to IDC [20], spending on public cloud computing will increase from $67B in 2015 to $162B in 2020, enabling 1.9 million new jobs and $389B in revenue [21]. Figure 3 depicts the worldwide spending on cloud IT services from 2016 to 2022.

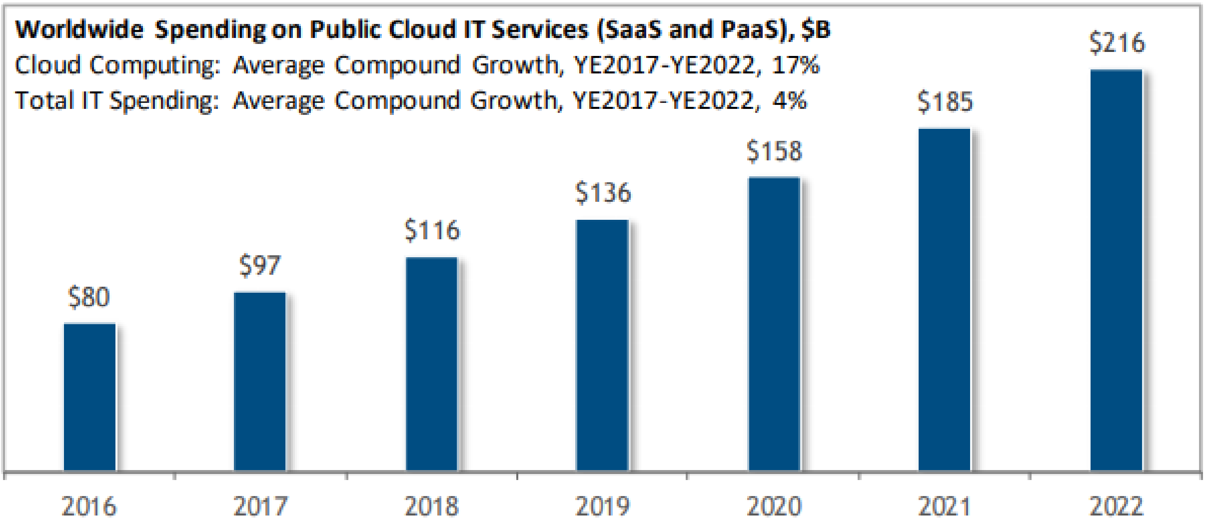

Figure 3 The rapid growth of cloud computing software, 2016-2022 [21].

With new enterprises moving to the cloud, these solutions have become mainstream in business as well as personal life. The uses of cloud computing are not limited to personal emails or storage, rather these scalable solutions have become the medium of choice for development, testing and deployment of software as well. Examples of cloud computing implementations are everywhere, from messaging apps to audio and video streaming services [22].

On the other hand, cloud adoption in Europe was not widespread till 2017. Up till 2016, only 21% of EU enterprises, mostly start-ups, were using cloud services. According to [23], this was because of data protection regulations since each country in Europe had their unique legislation regarding data processing. The situation changed in 2017 with the approval of the General Data Protection Regulation (GDPR). Businesses saw the opportunity to combine the on-premises infrastructure with the scalability and availability of the public cloud. A study performed in 2018 by 451 Research [24], showed that about 80% of EU-based businesses were in the stage of designing their cloud transition strategy or are currently going through the transition phase.

The rest of this section presents some examples of cloud computing implementation along with the features of cloud that have led to its popularity in the market.

2.1 Examples of cloud computing implementation

1. *Netflix* [25] uses cloud computing advantage of scalability to manage spikes in demands without the need to permanently invest in computer hardware. The move to migrate from in-house data centers to cloud allowed the company to expand its customers base without needing to invest in setup and maintenance of costly infrastructure [22].
2. *AI Chatbots* (e.g., Siri [26], Alexa [27] and Google Assistant [28]) utilize the expanded computing power and capacity of the cloud to store information about user preferences, providing customized solutions, messages and products based on the needs and the behaviour of users [22].
3. *Communication tools* (e.g., Skype [29], WhatsApp [30]) are based on cloud infrastructure which allows users to enjoy network-based access to their emails, messages, calendars, etc. All this information is stored on the service provider's hardware and is accessed through the Internet [22].
4. *Productivity tools* (e.g., Microsoft Office 365 [31], Google Docs [32]) run through cloud infrastructure allowing the users to use these applications anywhere anytime.

Moreover, data is stored in the cloud and can be shared online with multiple users, who for example want to work on the same document at the same time [22].

5. *Business processes*, for example customer relationship management (CRM) and enterprise resource planning (ERP) tools are based on a cloud service provider. Software as a Service (SaaS) has become a popular method for deploying enterprise level software [22]. Some examples of this model are Salesforce [12], Hubspot [33] and Marketo [34].
6. *Backup and recovery tools* (e.g., Dropbox [35], Google Drive [36], Amazon S3 [37]) are also cloud-based. Cloud service providers are responsible for data storage, security and meeting legal and compliance requirements. Data is stored and retrieved on demand by the users and recovery is faster via the cloud [22].
7. *Application development* becomes easier through cloud platforms either for web applications, mobile apps or even games. Using the cloud, scalable cross-platform experiences are created for the users. These cloud platforms include pre-coded tools and libraries, speeding up and simplifying the development process [22]. Amazon Lumberyard [38] is one example of mobile game development in the cloud.
8. *Test and development* of applications and software can be done in the cloud, saving the development team expenses and project time that are needed to setup a physical testing environment. These dev-test cloud environments can be scaled up or down based on requirements [22]. LoadStorm [39] and BlazeMeter [40] are two examples of such cloud-based testing environments.
9. *Big data* analytics can be performed in the cloud. Cloud computing enables data scientists to tap into any organizational data to analyze it for patterns and insights, find correlations make predictions, forecast future crisis and help in data backed decision making. Cloud services make mining massive amounts of data possible by providing higher processing power and sophisticated tools [22]. Open source big data tools are for example Hadoop [41], Cassandra [42] and HPCC Systems [43].
10. *Social networking* is also done in the cloud. Facebook [44], LinkedIn [45] and Twitter [46], and other social networking sites that are used for sharing information between users, require a powerful hosting solution to manage and store data in real-time, making the use of cloud solutions critical [22].

2.2 Adoption of Cloud Computing in Industry – Amazon case

An example of cloud computing adoption in industry is Amazon’s picking system of orders using interconnected robots. KIVA robots work on the principles of cloud computing. Kiva robots are contacted with the location information of a product in the warehouse, the moment a customer presses “check-out”. These robots, formerly under Kiva Systems and now Amazon Robotics, are programmed to travel in the four cardinal directions to reach their destination. To reduce congestion in the warehouse’s “highways,” the robots are told to travel underneath shelves as much as possible. Once at the desired shelf, the devices do a corkscrew motion to lift the shelf off the ground and transport the entire unit to the queue line where humans pack the appropriate items. The robot then travels back into storage and finds a new spot in an area with densely filled shelves [47].

3 Expected trends in cloud computing

As mentioned many times before in this paper, the adoption of cloud computing can bring many benefits, however larger organizations are still hesitant to transfer their information to the cloud, mainly because of security risks. But even with the security concerns, cloud services adoption continues to rise, and according to UnfoldLabs [48], this rise is due to the improved usage of cloud-based services including mobility, increased efficiency, cost-effectiveness, streamlined collaboration, and speed of connectivity.

3.1 Market trends data points

- “Enterprise cloud spending is growing at 16% CAGR between 2016 and 2016”, says SiliconANGLE [49].
- “At least half of IT spending will be Cloud-based in 2018, reaching 60% of all IT infrastructure, and 60–70% of all software, services, and technology spending by 2020. It is also predicted that in the same year, cloud will be the preferred delivery mechanism for analytics”, reveals IDC in a relevant study [21].
- “Spending on IT-as-a-Service for data centers, software and services reaches $547B in the end of 2018”, according to a study performed by Deloitte [50].

The new advantages of cloud computing that will influence the market’s growth potential include: easily deployable models; simplified IT management and maintenance; built-in security; and reliable delivery, management and support services [48].

3.2 Trends for 2019

1. *Growth in Cloud Services and Solutions*: More and more organizations are choosing Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) to support their business operations [48] [51].
2. *Hybrid Cloud Solutions*: The hybrid cloud model offers a transition solution that mixes the existing on-premises infrastructure with public cloud and private cloud services, enabling companies to transition to the cloud at their own pace while being efficient and flexible [49].
3. *Automation in the Cloud*: Companies of all sizes will be looking to manage their cloud architecture with tools that offer automation solution to different processes. Automation will simplify cloud administrators’ jobs by saving costs and time, and eliminating manual processes such as sizing, provisioning or backup jobs [49].
4. *Internet of Things (IoT) and the Cloud*: Most IoT devices rely on the cloud to work, especially when these connected devices work together. IoT connected devices like household appliances, cars, and electronics, have a cloud-based back end as a means to communicate and store information. The cloud supports these devices, and as we see more IoT devices being made and sold, the cloud usage will continue to increase as a result [46].
5. *Serverless Cloud Computing*: It allows developers to build and run applications and services without worrying about managing/operating servers, increasing cloud usage, and cloud use cases. In addition to not having to manage any infrastructure, Serverless Cloud Computing also improves efficiency by allowing developers to connect and extend cloud services to easily address their applications and multiple use cases. Serverless Cloud Computing requires less time and effort, and simplifies the release of new updates [52].
6. *Edge Computing*: Performing data processing at the edge of the network to optimize cloud computing is expected to be on the rise for 2019. It is a result of increased usage of internet-connected devices. Using Edge computing will be required to run the real-time services as it streamlines the flow of traffic from IoT devices and provides real-time local data analysis and analytics [46].

4 Implications of cloud computing on future job market in the EU

With cloud computing market on the rise, as explained in Sections 2 and 3, organizations are becoming aware of the need to upskill both their technical and business knowledge in order to understand the shift cloud computing introduces, how to capitalize on the benefits that cloud adoption brings, and how to manage and integrate cloud computing and cloud-based services.

Training and education is needed for practitioners to understand, work with and benefit from this technology [53].

4.1 Key competencies in Cloud Computing

New competencies that cloud computing require are in close connection with its architecture, and the benefits and challenges that come along with this technology. Table 1 summarizes competencies and potential roles within cloud computing in accordance with the challenges, as described by [54].

Table 1 Competencies and emerging roles in Cloud Computing as identified by [54].

Challenge	**Competency**	**Emerging role**
Availability/ Reliability	- The current disaster management processes would need to undergo changes to reflect the move to the Cloud. Further, while the Cloud promises to take care of disaster recovery planning for organizations, Cloud outages still point to the need to plan for disasters. - SLAs must be ideally set up between customers and cloud providers to act as warranty. An SLA specifies the details of the service to be provided, including availability and performance guarantees.	**Provisioning Manager**
Security	- Current cloud offerings are essentially public. For this reason, there are potentially additional challenges to make cloud computing environments as secure as in-house IT systems.	**Security and Compliance Manager**
Integration/ Customization	- Bridges the technology domains, ensure the coherence of the computing environment, and manage the evolution of the cloud platform for end-to-end business services.	**Cloud Architect**
Vendor Management	- Manages relationships with cloud providers and cloud service brokers, and incorporates them as needed into the services management and delivery process. - IT shift from being an internal provider of services to a manager of external service providers.	**Vendor Manager**
Cultural Resistance	- Change management. - Manages the development of competencies.	**Training Manager**
Transition and Execution	- Manages the configuration, operation and performance of cloud environments for various business purposes and services. - Assesses critical business drivers for cloud migration.	**Cloud Analyst**

4.2 Impact on job market in EU

Cloud computing has the potential to create high-skilled jobs in EU, specialized in the IT and technological profiles. In September 2012, the European Commission adopted a strategy for unleashing the potential of cloud computing in Europe. The European Cloud Computing Strategy (ECCS) outlines actions to deliver a net gain of 2.5 million new European jobs and an annual boost of €160B, around 1% of GDP, by 2020. It is also designed to speed up and increase the use of cloud computing across the economy [55].

Part of the ECCS's implementation includes the establishment of a Cloud Select Industry Group, C-SIG, which was created with the intention of providing independent validation and advice on cloud computing adoption and the challenges that lie within [56].

The ability to streamline and cut costs through virtualization, automation, and simplification of software setup usually means IT departments can do more with fewer resources in certain areas, but it also means that funds can be freed up and can potentially be reallocated to other areas of IT where more personnel are needed [57]. Some IT jobs will cease to exist while others will change and evolve to match with the technology requirements. That does not necessarily mean that people will lose their job, rather that employees will change roles and learn new, necessary skills.

In addition, if more companies are taking advantage of cloud computing, the vendors that provide these services and related infrastructure are going to have to grow to keep up with the demand. For example, a quick search on a job site will demonstrate that several IT vendors are interested in ramping up their cloud computing efforts and are hiring accordingly [55].

Finally, a study conducted in 2016 by the European Commission, showed that the already growing market of cloud computing could lead to the creation of 303K new businesses between 2015 to 2020, with most of them being SMEs [58].

5 Conclusion

Cloud computing is not a new technology as it appeared several decades ago. The rapid growth of using cloud-based technologies, which started in 2009 till today, in various industries and environments is an impossible fact to be denied. Cloud technologies have enhanced the efficiency and reliability by providing significant opportunities. From reduction of ICT costs and the shift of these costs to operating expenses, to scalability, adaptability and decreased time to market, cloud computing has proven to be a desirable solution for enterprises and has attracted many researchers, industrialists, investors and governments. Furthermore, the rapid growth of cloud computing has encouraged popular IT companies to introduce various cloud-based services, satisfying a variety of markets and their respective needs. Trends have shown that cloud adoption and use by almost everyone will happen eventually, and the many challenges of this technology will be overcome. Finally, cloud computing has opened a new era of IT skills, creating millions of new jobs worldwide and especially in Europe for the last couple of years, causing a positive impact on the European economy. With technology advancing day after day, it will be interesting to watch how this particularly useful service will evolve in the near future.

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3D Printing for Industry 4.0

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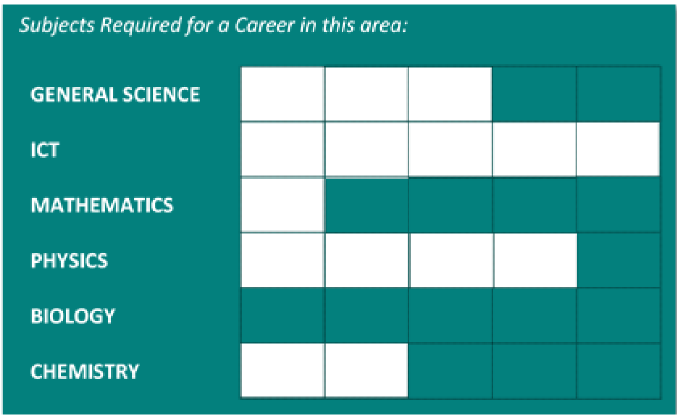
3D printing (3DP), also known as Additive manufacturing, is a general term for those technologies that build three dimensional physical objects from a digital file by successive addition of material, layer by layer. For more than 30 years it was used primarily for prototyping but, thanks to its new advances, it expanded into many applications for a range of industries and businesses and has now the ability to play an important role in the factories of the future.

3DP is a key technology and enabler of Industry 4.0 facilitating the decentralization by allowing the distribution the workload over the factories and machines via cloud services.

3DP is disrupting the way physical goods are developed, produced and distributed, affecting entire business models and value chains, opening up new market opportunities and transforming the supply chains. Consequently, 3DP is also a powerful driver for changes in employment and it will affect the EU job market in various ways. 3DP will have a significant impact on the future of peoples, companies and nations.

With the increase of 3DP use in EU industry, the need for suitable qualified workforce will grow at a rapid pace. On the other hand, some jobs will became redundant and others will undergo big transformations. These changes will favour those who are skilled and highly qualified in 3DP while no or low skill jobs are at high risk.



Subjects Required for a Career in this area:

GENERAL SCIENCE	⬜	⬜	⬜	■	■
ICT	⬜	⬜	⬜	⬜	⬜
MATHEMATICS	⬜	■	■	■	■
PHYSICS	⬜	⬜	⬜	⬜	■
BIOLOGY	■	■	■	■	■
CHEMISTRY	⬜	⬜	■	■	■

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1 Introduction

3D printing (3DP), also known as Additive manufacturing (AM), is a general term for those technologies that build three dimensional physical objects from a digital file by successive addition of material. As opposed to subtractive manufacturing methodologies which rely on the removal of material, in AM the material is added in successive layers until the complete object is manufactured.

The first 3D printers have been used since the1980s but they were large, expensive, and with very limited production capacities. Since then, tremendous progress has been made in 3DP in both capabilities and costs. Thanks to the recent developments driving down prices and complexity of 3D printers, 3DP is rapidly becoming available to the masses and is widely adopted across all industries.

3DP is considered a manufacturing revolution and is disrupting the way physical goods are developed, produced and distributed. It has an impact on entire business models and value chains, opens up new market opportunities and transforms the supply chains. It also facilitates the decentralization by distributing the workload over the factories and machines via cloud services. 3DP is a key technology and enabler of Industry 4.0.

1.1 3D printing workflow

Generally, 3DP involves the use of a computer, a digital 3D model, a 3D printing slicer software, a 3D printer and specific materials.

3D printing starts with the digital 3D model of the object to be printed. Next, the 3D model, converted to a mesh file (usually STL format), has to be sliced into a set of 2D sections having the desired thickness, which are then fed into a 3D printer that lays downs or adds successive layers of liquid, powder, sheet material or other, in a layer-upon-layer fashion to fabricate a 3D object from metals, ceramics, polymers, composites, biological materials, etc. A typical 3DP workflow is schematized in Figure 1.

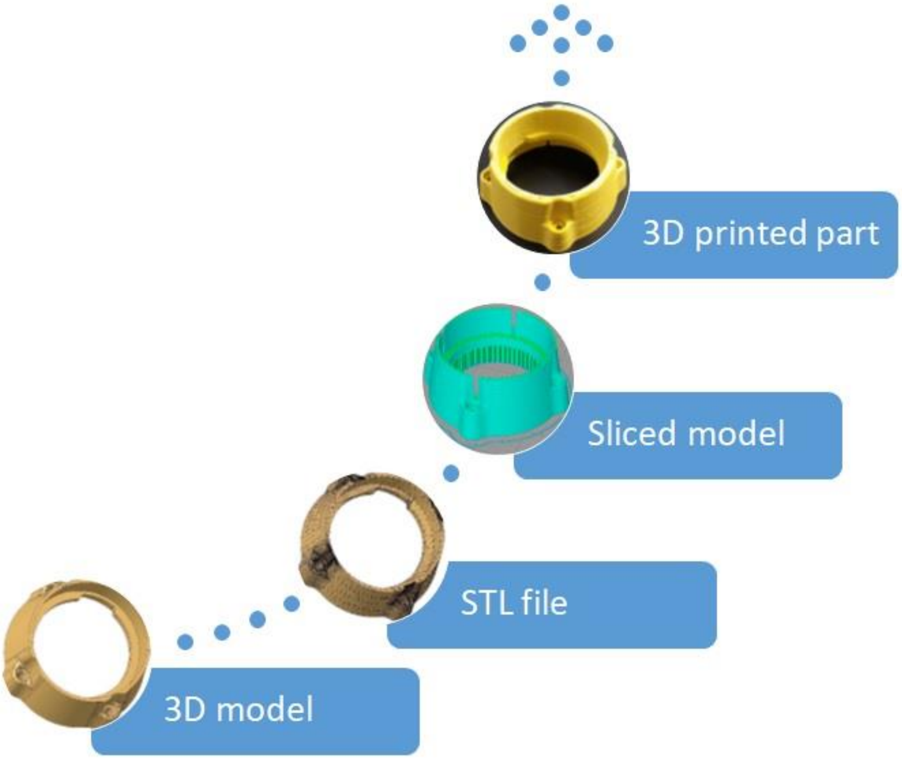

Figure 1. 3D printing workflow

The digital models required for 3DP can be obtained in several ways:

- Create them 3D computer graphics software (computer-aided design (CAD), sculpting and modelling software) [1]
- 3D scan an existing object, using 3D scanning devices or even mobile applications able to generate 3D models using the embedded camera of a smartphone [2]
- Downloading from Online Marketplaces, free or paid [3]
- Hire a designer [4]

The conversion of a 3D model to a STL file is normally possible with most of the software used to create it. Also, there are many converters supporting the translation of virtually any type of 3D geometry into STL files.

A 3D printing slicer software prepares the 3D model for the 3D printer, generating g-code, which is a widely used numerical control programming language. There is a large number of slicing software, many of which is free [5]. This step is also useful for checking the STL file for errors and printability.

1.2 3DP processes

3DP is actually an umbrella term that covers a group of individual 3D printing processes which vary depending on the material and machine technology used. The ISO/ASTM 52900 standard, created in 2015, classified the AM processes into 7 categories [6]:

- Vat photopolymerisation
- Binder jetting
- Material jetting
- Material extrusion
- Powder bed fusion
- Sheet lamination
- Directed energy deposition

The AM processes can be also classified based on the state of the raw material used:

- liquid
- powder,
- solid (sheet, filament, pellet)
- slurry

1.3 3D printing technologies

Many different types of 3DP technology have been developed based on the previously mentioned AM processes and are used by today 3D printers. Some of the more widespread are listed below:

- Fused Deposition Modeling (FDM)
- Stereo lithography (SLA)
- Digital Light Processing (DLP)
- Selective Laser Sintering (SLS)
- Material Jetting (MJ)
- Drop on Demand (DOD)
- Sand Binder Jetting
- Metal Binder Jetting
- Direct Metal Laser Sintering (DMLS)
- Selective Laser Melting (SLM)
- Electron Beam Melting (EBM)

- Laminated object manufacturing (LOM)
- Digital Light Synthesis (DLS)
- Bound Metal Deposition (BMD)
- Single Pass Jetting (SPJ)
- Wire + Arc Additive Manufacturing (WAAM)

1.4 Fused Deposition Modelling (FDM)

FDM (sometimes is referred to as Fused Filament Fabrication - FFF) is a 3DP technology that uses a continuous filament of material. It is based on Material extrusion process and works by laying down consecutive layers of material at high temperatures, allowing the adjacent layers to cool and bond together before the next layer is deposited.

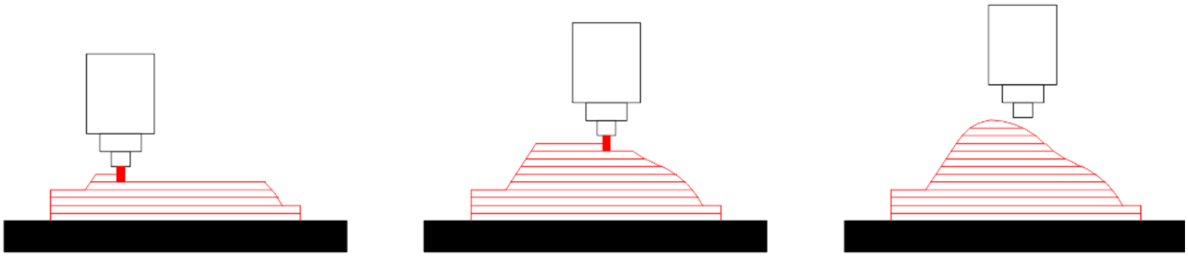

Figure 2. Schematics of 3D object building by FDM

1.5 Stereolithography (SLA)

SLA was the world's first 3D printing technology and is based on Vat Polymerization process where a photo-polymer resin in a vat is selectively cured by a light source.
An SLA printer uses mirrors which rapidly aim a laser beam across a vat of resin, selectively curing and solidifying a cross-section of the object inside this build area, building it up layer by layer.

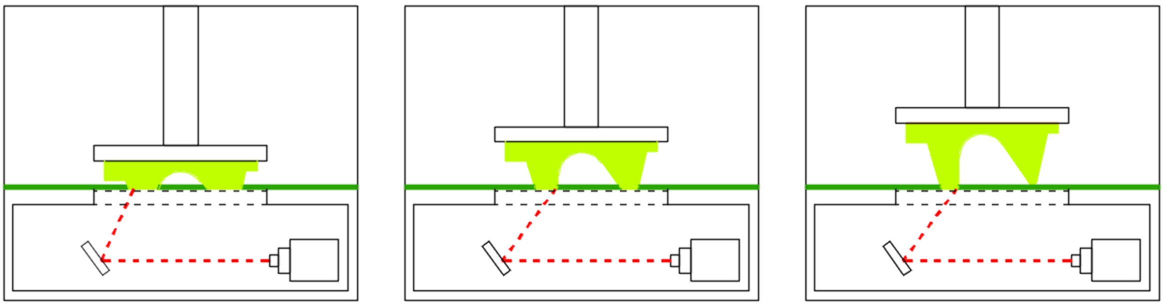

Figure 3. Schematics of 3D object building by SLA

1.6 Digital Light Processing (DLP)

DLP is very similar to SLA except the former uses a digital light projector to flash a single image of each layer all at once (or multiple flashes for larger parts). Also, DLP can print much faster because an entire layer is exposed all at once, rather than tracing the cross-sectional area with the point of a laser.

1.6.1 Selective Laser Sintering (SLS)

SLS is based on Powder Bed Fusion technology where a thermal energy source will selectively induce fusion between powder particles inside a build area to create a solid object.

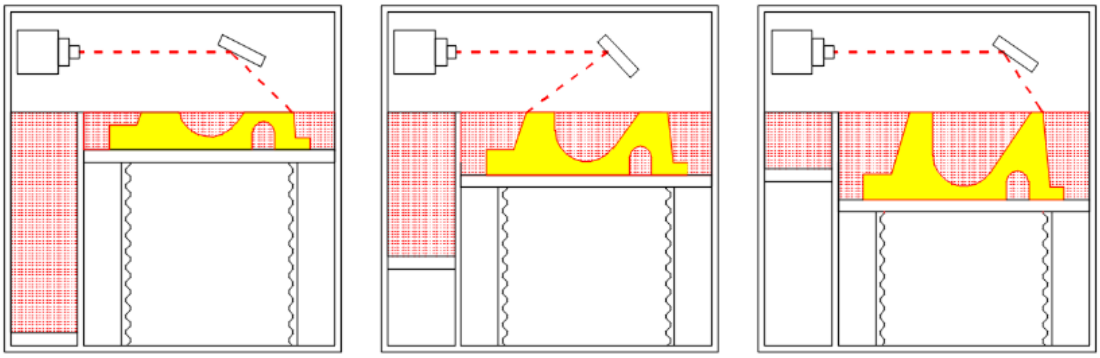

Figure 4. Schematics of 3D object building by SLS

1.7 3DP advantages

3DP provides several key advantages over traditional manufacturing techniques, in terms of cost and time efficiency, complexity of design, sustainability, etc.

1.7.1 Efficient objects customization

3DP allows for effective designing of a supply chain to meet the particular needs of individual consumers or unique businesses. Customization of products by 3DP involves virtually no additional costs as only their 3D file needs to be updated. The price of producing a part doesn't depend on the number of parts being 3D printed. Thus, to produce 1,000 identical parts or 1,000 slightly personalized parts it comes at virtually the same cost.

1.7.2 Unique freedom of design

3DP affords the creation of very complex shapes and geometries, sometimes impossible or very expensive to obtain with other methods. This has a big impact on the creativity as design is no longer restricted by the traditional manufacturing limitations.

1.7.3 No need for tooling

3DP doesn't require the initial cost of molds, jigs or other specific tooling specific for traditional manufacturing methods and, consequently, it is very convenient for production of unique parts or small batches as well as for mass customization.

1.7.4 Cheaper, faster and easier product development and prototyping

The development of tangible products involves a cyclic process of prototyping, testing, analyzing, and refining an idea. Most of the times, prototyping by 3DP is faster, cheaper and easier than with traditional technologies and, thus, facilitates quick design iterations and, consequently, faster product development.

1.7.5 Risks mitigation when a new product is launched

The risks related to a new product is launched on the market can be mitigated through a series of actions. The risk of investing in expensive manufacturing equipment for a faulty product can by significantly reduced by testing on 3D printed production-ready prototype. Also, the market can be tested with small batches of the product made by 3DP, before making the large investments required for mass production.

1.7.6 Less waste produced

As an additive process, 3DP generally only use the amount of material needed to build a part so less waste is produced. The materials used by most 3DP processes can be recycled or reused for more than one build, thus very little waste being produced.

1.8 3DP Limitations

3DP is not always the right tool for the job. It has some limitations, ranging from the restricted availability of materials to reduced speed and high costs.

1.8.1 Higher cost for large production runs

The unit cost of 3D printing remains constant regardless of the number of parts produced while for traditional manufacturing methods the unit cost decreases with the increase of the production run.

Consequently, 3DP can be more economical for a small batch but, as the production run increases, the traditional manufacturing methods become more price competitive than 3DP.

1.8.2 Reduced material choices, colors, finishes

The range of materials that can be 3D printed is quite limited nowadays, plastics being the most used materials.

1.8.3 Limited strength and endurance

The layer-by-layer fabrication process typical for 3DP adversely affects the part strength uniformity. This often makes the 3D printed parts weaker than their traditionally manufactured equivalents.

1.8.4 Low accuracy, low surface and small details quality

The accuracy of a 3D printed object depends heavily on various factors: type of process, design, materials, warping or shrinkage, supports used, equipment settings, etc. and is lower than what can be achieved with CNC machining, for example. Also, the surface quality is not very good.

1.8.5 High energy consumption

3D printers consume much more energy than traditional manufacturing.

1.8.6 3D printers are slow

With the current technology, manufacturing by 3DP is very slow. It can take from several hours to several days to print an object, depending on many factors: object size, desired resolution, material, type of process, printer quality, etc.

2 State of the implementation of 3DP

2.1 3D printing adoption

3DP emerged several decades ago but only recently has the technology experienced rapid growth, expanding into many applications for a range of industries and businesses.

Additive manufacturing was originally intended exclusively for high level industrial use and was very expensive. However, the constant decrease in cost made it affordable for SMEs and individual entrepreneurs and, in the last years, home 3D printers became available at very reasonable prices. Nowadays, 3DP is progressively becoming a technology any business can afford and many companies have already started to integrate 3DP into their business model.

Beyond being used by companies, there is a growing trend of using 3D printing in consumer markets.

The 3D printing adoption experienced a rapid grow in the last years and it will continue to grow fast in the next period. According to Wohlers Report 2018 [7], an estimated 528,952 desktop 3D printers and 1,768 metal 3D printers have been sold in 2017. These numbers are expected to grow with at a steady pace

According to The State of 3D Printing, 2018 published by Sculpteo [8], the most popular applications of 3DP in 2018 were:

- prototyping (55%)
- production (43%)
- proof of concept (41%)
- Marketing samples (18%)
- Art (16%)
- Education (16%)
- Hobby (10%)

This clearly shows that, currently, companies are heavily relying on 3DP for accelerating product development. Also, it is evident that professionals are using 3DP for more purposes than before, implementing it in not only in prototyping but in more of their activities.

2.2 Current uses of 3D printing

For more than three decades, 3DP was used primarily for product development. However, in the last years it has developed enough to play critical roles in many areas, the most important ones being manufacturing, medical industry, automotive, aerospace and design.

3DP use in manufacturing of component parts, finished goods and other items has gradually increased over the years. 3D printed tools, jigs and fixtures are also employed to augment or support manufacturing operations. Already, manufacturing by 3DP is a reality in Aerospace (for example, 3D printed parts are used in Airbus aircrafts), Medical Devices (for example, the production of artificial hip joints and dental crowns and bridges) and other sectors.

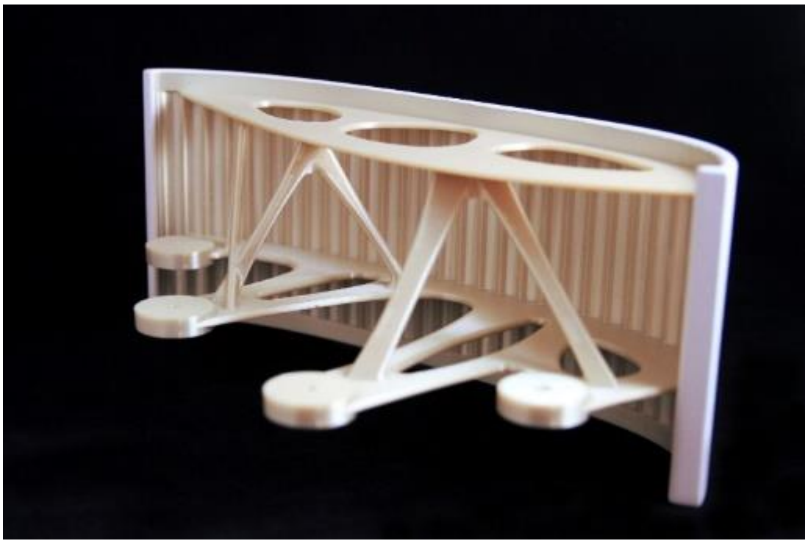

Figure 5. 3D printed spacer panel installed aboard an Airbus 320. Image credits: Airbus

Medical sector is one of the industries that benefits the most from 3DP. Prosthesis, made-to-measure implants, orthodontic parts, customized drugs or bio-printed organs are just some of the existing applications. 3D printed models of patients' body parts or organs are used by doctors for treatment planning and visualization and to plan and practice surgeries, potentially saving lives.

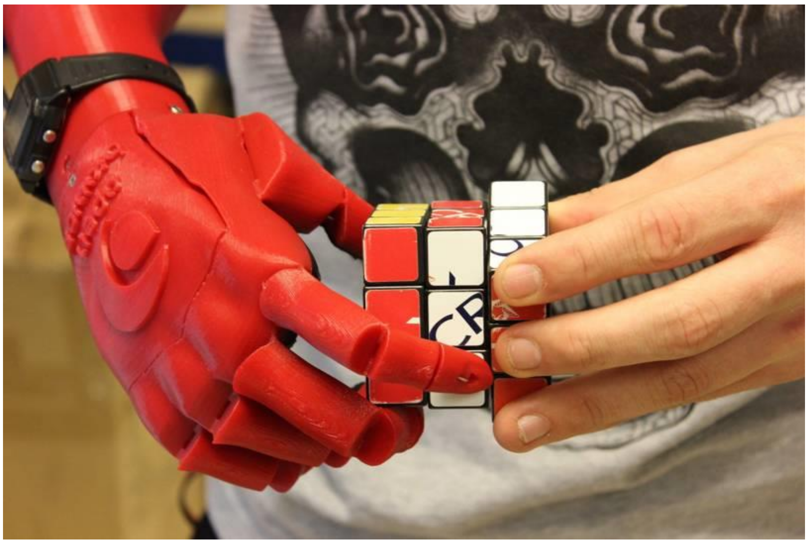

Figure 6. 3D printed bionic arm. Image credits: Open Bionics

Currently, there is a growing interest of the automotive industry for 3DP. Several cars and motorcycles with most of their parts 3D printed, produced by Divergent3D and Local Motors to showcase the technology potential, are already on the streets. A proof-of-concept model for a 3D printed electric car to be mass-produced has been unveiled by XEV in 2018. BMW used more than 1 million 3D printed parts for its cars in the last 10 years and many other car producers are using 3DP to create full parts or prototypes.

Figure 7. The world's first 3D printed supercar. Image credits: Divergent3D

Many designers are utilizing 3DP in creating jewelry, furniture, fashion, lighting fixtures, art objects and so on. It gives designers a wide range of possibilities and a huge freedom of creativity.

Figure 8. 3D printed jewels. Photo credits: Shapeways

3 Expected trends in 3D printing

3.1 Introduction

3DP is a very dynamic industry with many rapid developments in many different areas, from equipment, software, materials, processes and applications to legal, financial and human resources aspects. It is also an industry that has a significant impact on the future of peoples, companies and nations. Consequently, there are many probable trends and possible directions of expansion related to 3DP. In this section, we will discuss only some of them that are relevant for our target group: STEM teachers and their students.

3.2 Substantial grow of global 3DP market

The analysts and the 3DP stakeholders do expect significant growth within the next years [9, 10, 11]. The 3DP adoption will continue to expand into different industries leading to large increase in sales of 3DP products and services.

The factors facilitating the growth are:

- the ease of development of customized products
- ability to decrease overall manufacturing costs
- European Union and national governments investments in projects for the development and deployment of 3DP

- businesses will continue to expand their 3DP efforts finding ways to implement 3DP effectively
- an increasing number of new entrants, including large companies
- development of new materials
- development of larger, faster and more capable 3D printers
- development of new technologies (especially related to metal 3DP).

According to the most 3DP experts, the investment in 3DP exploded in the last years and it will continue to grow at a steady pace. Apart the increase in the number of 3DP systems sold, many companies are investing in new Research and Development 3D printing centers and new manufacturing facilities while European Union and a number of national governments have committed huge resources to the development and advancement of 3DP.

3.3 3DP technology development

3DP hardware has evolved significantly in recent years and is estimated the same in the next period.
Also, 3DP software will continue to develop offering user-friendliness, higher speed, workflow improvements, files security and better predictive capabilities, feedback and guidance. The simulation software will be able to predict failures before they happen and to permit the optimization of printing parameters allowing higher accuracy and lower scrap rate. This is crucial especially in the case of applications where the cost of raw material is very high.
3DP, as a whole, will improve thanks to new materials, quicker post-processing and 3D printers increased monitoring, allowing better in-process inspection. Also, new 3DP processes will continue to arrive, including hybrid processes like 3DP and CNC or multi-material.

3.4 Metal 3D printing

A major increase is expected in metal 3D printing as more and more companies are pursuing creating metal 3D printers with various processes. Also, global manufacturers are becoming aware of the benefits of producing metal parts by 3DP. These parts are particularly attractive in markets such as aerospace, defense, medical devices, and manufacturing systems.
Some 3DP processes that allows for fabrication of metal parts with lower costs than traditional metal and ceramic additive manufacturing technologies have been developed. Thus, metal 3D printing is now becoming accessible to small and medium-sized enterprises and the trend to lower selling prices and increased sales and, consequently, to metal 3DP adoption at a large scale, is accelerating.

3.5 Increasing use in manufacturing

While rapid prototyping is the most common use for 3DP, its future is in manufacturing of full parts. Thanks to the advances in equipment and materials, 3DP has now the ability to deliver parts with the mechanical properties and quality required for given functions.
In the next few years, 3DP is expected to become much more widely used in all kinds of manufacturing [12]. 3DP can potentially replace conventional manufacturing methods in low and medium volume manufacturing. Also, 3DP becomes feasible for personalized and low-volume products, given its ability to customize products without requiring new tooling.
3DP offers exceptional flexibility in manufacturing as is enough to update the CAD model in order to create different product variants. These design modifications do not have major economic implications and the unitary cost of production remains virtually the same. Also, the

lead times in the case of low volume production is much lower with respect to the conventional manufacturing methods.

Other great advantages of 3DP, like design freedom, no need for tooling, lighter parts, and simplified assembly are leading to an increasing demand for its use in manufacturing.

Already, 3DP manufacturing is employed in several sectors. There is an increasing trend toward cost-effective manufacturing and rapid production so the production of parts using 3DP is expected to grow.

3.6 Increasing use in healthcare

According to a study published by Gartner in December 2018 [11], the 3DP application in healthcare is accelerating and will play an essential role in the next decade. The report foresee an increase in the use of 3DP for pre-surgical planning (e.g., anatomical models) and in performing joint replacement, surgical implants and prosthetics. 25% of medical devices in developed markets will make use of 3D printing by 2023.

3.7 Increasing demand of 3DP skilled workforce

The massive growth of the 3DP market led to skills gap, so a considerable increase in the demand for suitable skilled staff is expected.

Companies can employ several strategies that to manage the skills gap: hire new staff already possessing skills relevant to 3DP, retrain existing employees, expect existing employees to pick up skills on the job, hire freelancers with 3DP skills or outsourcing some business functions to external contractors.

Individuals that want to train themselves, can do it in house or using various resources: 3DP blogs, events and training sessions, both face-to-face and online. There is an increasing number of classes focused on 3D printing technologies, projects focused on education in 3DP, courses, publications, etc.

3.8 Automation

The 3DP automation allows for increasing throughput, speeding up production, reducing the operational cost and increasing efficiency. It could be done by automating the printers themselves and/or by using robotic arms that assist in the production process.

Software also makes it possible to automate tasks throughout the 3DP process.

The 3DP automation trend could be seen as a part of the larger transition of 3DP into a production technology and it’s extremely important for the integration of 3DP in the smart factories.

Several automated 3DP systems already exist on the market and other will come soon.

Figure 9. 3DP process automation (Image credits: Voodoo Manufacturing)

3.9 Increasing printing speed

Nowadays, 3DP is very slow and this obstructs its use in a number of applications. However, there is a clear trend to solve this issue via special software algorithms, improved hardware and new technologies. The post-processing of parts will be also quicker as more support material and automated finishing options become available.
According to Siemens, 3DP will be up to 400 percent faster in the next five years.

3.10 Decreasing costs

One of the most important trends is the dropping of 3D printers prices due to a very competitive landscape and as the technology scales and advances. This will increase sales and multiply 3DP applications.
Several new metal 3DP processes significantly less expensive than the traditional approaches have been recently introduced and they will bring down the costs of metal 3D printed parts.
As more companies implements 3DP systems, this proliferation and subsequent added volume are driving down the material prices, also. According to Siemens [13], 3DP will be 50 percent cheaper in the next five years.

3.11 New 3DP materials

Plastic is the most common material for 3D printing but the use of metal will become more popular in the following years. Regarding plastics, new higher-temperature engineering materials are expected to appear. Also, as the resin-based 3D printers recently undergone an impressive growth, more powerful resins will be developed in the future.
New materials will be developed from all categories (plastics, metals, ceramics, composites, etc.).
The rise of manufacturing applications is fueling a growth in materials development and attracts large material suppliers, like the chemical companies, into 3DP sector.

3.12 Widening of applications range

The further development of 3DP industry will be accelerated by the identification of new applications for 3DP. More and more companies will focus on niche targeting within 3D printing.

There are many industries already taking advantage of using 3DP, including healthcare, aerospace, automotive, and many others. In other industries, 3DP is still at its initial stages but it will definitely play a major role in the future. Some examples: construction, consumer products, food industry.

New industries will embrace AM. For example, 3D-printed fuel nozzles for gas turbines will make power plants cleaner and more cost-effective.

Also, industries with operations in remote locations, like mining, oil and gas, defense, etc. will use 3DP for on-site manufacturing of spare and replacement parts or for repairing existing parts.

In a study published by World Economic Forum [14], a large number of companies from 12 industrial sectors indicated their intention to adopt 3DP technology by 2022. The sectors are ranging from automotive, aerospace, supply chain & transport to chemistry, consumer, energy, healthcare, IT&C, infrastructure, mining, oil & gas and others.

4 Implications of 3D printing on future job market in EU

4.1 Introduction

3DP is a powerful driver for changes in employment and it will affect the EU job market in various ways. With the increase of 3DP use in EU industry, the need for suitable qualified workforce will grow at a rapid pace. On the other hand, some jobs will became redundant and others will undergo big transformations in their content (tasks, working methods, required skill set).

The 3DP progress will favor those who are skilled and highly qualified in 3DP while no or low skill jobs are most at risk. Also, the ability to learn fast and to adapt to new fields will be crucial for having a successful carrier.

The different steps of the 3DP process (design, installation, safety, operation, post-processing) must be covered by qualified workers. Also, other operations, including investment, legal issues, training, etc. may need key personnel with appropriate knowledge.

Various professions will be on demand: engineers who work on production processes or develop new technologies, materials, software and applications, designers, including artists who create products and projects using 3D printers, salespeople, project managers, and lawyers, who will take care of patents and copyrights issues.

Sectors that are currently recruiting professionals for 3D printing are medical, engineering, automotive and aerospace industries. The list of sectors that will recruit is continuously expanding as the technology improves and its adoptions grows.

4.2 Key competences in 3DP

For those looking for a future job in 3DP, there are some specific requirements that they must have in order to advance within a career. Typically, a quite vast knowledge, involving different specialties, is required when working in the 3DP sector. This must include the basics of 3DP along with other specialized knowledge, depending on the job profile.

The key competencies required by 3DP are:

- IC&T – due to the digital nature of 3DP technology
- CAD – required tool for 3D design

- Materials – it's necessary to know the characteristics and compatibilities of various materials in order to obtain objects with desirable properties and finishes
- Process – the professional has to decide on the suitability of the available technologies to achieve the required tolerances and finishes for each case

Consequently, there is a need for certain technical or design training to be able to use the 3DP technology.

In addition, some other skills and abilities will be required: flexibility, collaboration, digital navigation capabilities, the ability to handle high complexity, etc.

4.3 Impact on job market

4.3.1 Job Creation

3DP has the potential to create new higher-skilled jobs in EU, with an especially big demand for specialized and technical profiles. These profiles include industrial and mechanical engineers, software developers dedicated only to 3DP, software engineers working on 3DP specific problems (3D files repairing, workflow and process optimization, etc.), designers with 3DP knowledge, 3D printer technicians, 3DP material experts, post-processing specialists, 3DP consultants, etc.

The number of new jobs created around the 3DP industry will grow in the next years, even decades. There will be a need for people to fabricate, sell, operate, maintain and repair the 3DP equipment, manage the supply chains, oversee production and manage the companies that do all this.

3D modelling software, simulation software dedicated to 3DP and other specific software applications will create new jobs for programmers. In addition, entirely new job categories will be created thanks to the new wave of innovation brought on by 3DP.

4.3.2 Job changes

Some existing jobs will require new skills. For example, mechanical design for 3D printing needs specific knowledge and skills related to 3DP process and materials.

Also, machine tools operators will have to work with complex 3D printed parts instead of starting with a block of material. So the operators will not be replaced, but they have to learn a little different way of doing their job and acquire new skill set.

4.3.3 Job losses

Undoubtedly, a significant number of jobs within the manufacturing sector will disappear. As 3DP capabilities are growing and its adoption by the industry increases, there will be less staff needed on the production lines for machining, welding, assembling, etc. operations. Also, many jobs in jewelry and craft sectors will be threatened due to powerful capabilities of 3DP. This latter has the ability to efficiently manufacture products in local markets so it is expected that at least a part of the manufacturing jobs outsourced in China or other low-wages countries will come back in Europe.

5 Conclusion

In the recent years, 3D printing evolved from an expensive technology with very limited capabilities and applications, reserved only for large companies to a powerful tool easily affordable for business or individuals, with countless applications in a wide range of sectors. Nowadays, it is considered a key technology that enables the fourth industrial revolution, Industry 4.0.

3DP has the ability to disrupt many industries, to open up new market opportunities and to transform the supply chains. Also, it will have a significant impact on the global and EU job markets, with positive and negative effects. Skills and qualifications relevant for 3DP will be a key asset for those wanting to have a successful carrier and to take advantage on the new opportunities created.

The main trends in 3DP are toward market grow, technology development, increased use in various sectors, lower costs and wider applications range. Consequently, these will lead to an accelerated grow of 3DP adoption and to a more and more increasing demand for skilled workforce.

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Robotics

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Educational robotics has a high motivational component for young people. The lack of future workers with a technical profile threatens the future plans of our society.

Educational robotics is one of the pillars with which the Direction 4.0 project aims to motivate young people to choose scientific and technical training in order to serve an increasingly digital society. At present schools and training organisations are introducing into society the so-called educational robotics.

Schools and institutes are increasingly aware of the advantages of introducing robotics through workshops, courses or even subjects in the education of children and young people.

Subjects required for a career in this area					
GENERAL SCIENCE	□	□	□	■	■
ICT	□	□	□	□	■
MATHEMATICS	□	□	□	□	■
PHYSICS	□	□	□	■	■
BIOLOGY	■	■	■	■	■
CHEMISTRY	■	■	■	■	■

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1 Introduction

That robotics takes the steps of becoming something important for our current society is undeniable. When people in general are asked about the word robot or robotics, they usually see the robot as something inaccessible and / or dangerous, that is, they associate it with problems rather than relating it to something positive. The deficit of people with a technical profile that gives solution to a future society much more technological can complicate things. It is not enough to know how to press a button or to know how to surf the net, what is needed is people who are capable of creating content, applications, robots, etc., that society needs and will need in the near future. Through the Direction 4.0 project, we are trying to motivate young people to choose the path of science and technology in their educational development and this is where one of the objectives of educational robotics comes in. In educational robotics, we should differentiate between two concepts.

One thing is to make robots to teach and another point, or even complementary, is to train with robotics. You may introduce children and young people to the world of robotics, or you can also educate them and acquire knowledge of basic areas of teaching through it. Currently schools and training centres are promoting educational robotics.

Schools and institutes are increasingly aware of the advantages of introducing robotics through workshops, courses or even subjects in the education of children and young people.

Therefore, educational robotics due to its inherent motivational component has become a powerful tool for education.

2 Report on most recent state of implementation of Robotics

Using robotics and information science in the classroom increases the motivation of the students. Using robotics as a base, students can be initiated on topics such as computer programming, networks, artificial intelligence, etc. [12].

2.1 Background

During the lasts decades' researchers and industries have developed a number of kits for the construction of robots with the desire to stimulate the learning of concepts and methods related to areas such as mathematics, physics, computer science and mechanics. [1]. BEE-BOT, LEGO WeDo, LEGO Mindstorm, ARDUINO are usually used to teach robotics in education. The aim of educational robotics is, as Jean Piaget indicates, "who learns, broadens his knowledge through the manipulation and construction of objects" [2].

The United States, China, Korea, India, among others, were the first in implementing and offering workshops and extracurricular courses in robotics as an example of recreational activities [3] [4].

This table shows the evolution

YEAR	NAME	MAIN CHARACTERISTIC
1977	Lunar Rover	Exploring the Moon
1979	Stamford Car	Running on surfaces
1983	Raibert	Walking on one leg
1990	Uniciclo	Only one wheel

1994	Dante II	Six wheels
1996	Gyrover	No wheels
1996	Spring Flamingo	Emulation of a flamingo's movement
1997	Sojourner Rover	A Robot controlled from the Earth
1997	Honda P3	A Robot copying human movement
1998	Wabian R-III	A Humanlike Robot
1999	Bow Leg Hopper	A Robots which loads the power on one leg
2006	Ballbot	Movement provided by a single sphere

Table 1. (Source: S. R. Ortigoza, J. G. Sanchez, V. B. Sotelo, and M. M. Vilchis, “State of the art of the movable wheel’s robots”, Revista Electrónica de Estudios Técnicos, TELEMATIQUE, vol. 6, No. 3, 2004.)

2.2 Characteristics of the mobile platforms

There are a variety of robotic platforms that use different mobility mechanisms, most of the time the wheels are used because they stand out in their efficiency on the caterpillars and legs on smooth and firm surfaces. [5]

We can define a mobile robotic platform as an electromechanical system composed of a mobile mechanical part and an electronics, whose components behave like controlled actuators thanks to the high level of programming, and so achieving an intelligent system, which, thanks to its different types of wheels, allows the robot to move autonomously to a defined point or an established goal.

Autonomy here means the ability of the system to determine its course through a proprietary process of reasoning at the sensory level and not depending on a system of movement instructions [5]. The success of the autonomous tasks of the robotic system depends on its mechanical construction, which determines the precision of its displacement, while the intelligence depends on its programming.

2.2.1 Metallic structure with wheels

The wheels are the elements in charge of providing the mobility of the platform. They are classified into three types: those that are fixed, the movement of the platform goes into the direction of the wheel; those of centred orientation, where the direction depends on the orientation of the wheel [5]; finally, those with a dry wheel, where the direction depends on the speed of the wheels

2.2.2 Sensors

A sensor is a device which gives an output signal equivalent to the measurement; in robotics the sensor device is used to capture energy, while the transducer, to convert and condition it [6], so that the intelligent system can process it. They are in great variety according to the type of application. Among the types of sensors used in educational robotics we can find those measuring distance based on ultrasound composed of a high frequency sound emitter receiving a reflection by a receiver located in the sound source by a transmitting part, which emits a source of sound at high frequency to subsequently receive an echo where the attenuation or time of flight of the ultrasound is evaluated [7] [8] [9].

<u>Infrared sensors:</u> They are similar to ultrasonic and are composed of an infrared LED as emitter and a phototransistor as receiver [3]. Which is brought to saturation by means of light in its base, this makes them useful in mobile robotics when working with obstacles, since they are very precise due to their high directionality of light reflected in the receiver. There are many applications, such as measuring distances, passing objects in industrial bands and detecting the proximity of objects and people, sensors such as the QRD1114 [10]; ideal for mounting on mobile robotic platforms for obstacle avoidance and trajectory tracking. This is how infrared and ultrasound technology can be used in a complementary way, and the information from both sensors can be combined for the construction of a more accurate mapping or representation of a navigation area of a mobile robotic platform [11]

2.2.3 Actuators

They are used for motion control, the most common and commercial are direct current motors with reduction gearbox or gearboxes. As these are controlled in a linear way of its implementation on the platform is easier

These engines are with brushes and without brushes, both types have similar advantages, however brushless are much more practical because:

They do not present sparks or arcs due to the friction exerted by the carbon-copper material with the contacts of the armature.

The interference caused by electronic switching from the control system is minimized. Brushless dc motors reach speeds of up to 50,000 revolutions per minute versus 500 of one with brushes.

The control of direction is favoured, since it is a motor with brushes.

However, there are disadvantages that make brushless motors a better option as turning controls are accompanied by great complexity cost is higher and handling as it requires an additional control system.

2.2.4 Control

The control of movement can be classified in four fundamental tasks:

- Location.
- Path planning.
- Track tracking.
- Avoidance of obstacles.

3 Robotic platforms for education

Some of the robotic platforms for education, related to the age of the students are the following:

3.1 Students from 3 to 5 years' old

The BEE-BOT robot is a good option. This robot is shaped like a bee, it is resistant and very compact. Its programming is done in a simple way by pressing the buttons that indicate the direction, the change of direction, if it has to go forward or backward, etc.

3.2 From 6 to 9

One of the most widespread tools is LEGO, specifically the Lego WeDo. Through the pieces that make up the kit you can create a very eye-catching robot. Its programming is based on a block interface, which works by dragging blocks instead of writing instructions.

3.3 From 10 to 14

You can choose the Lego Mindstorm platform, unlike the Lego WeDo platform, this kit allows you to build more robots and allows the incorporation of more sensors and actuators.

Its programming is done through an IDE (development environment) where it will be programmed by dragging blocks with concrete actions.

3.4 From 15 onwards

One of the main platforms are the plates of the Arduino family, as Arduino UNO. It is usually advisable to start with this platform.

Other plates and robots based on Arduino are: The Faduino plate, the MoWay robot, the mBot robot. Other robots based on other plates are: the robot Aisoy, Vex Robotics, the humanoid Robotis robot, among others.

4 Expected trends

4.1 Background

Fifteen or twenty years ago, robotics was presented as something, not so difficult, but laborious and entertaining to perform.

The price of the Lego Mindstorm was quite expensive and if you opted to try it on the cheap side there was no reference plate, much less a plate assembled and ready to be used. There were some license plate schemes such as the "Picaxe", for example, which were distributed free of charge by some websites, as well as a list of the necessary components and a few instructions on how to carry out the entire process. The entire process of lithography, development and assembly was for the daring who wanted to try it.

Once everything was assembled, a PIC microcontroller recorder was required to transfer the programs to the small integrated circuit.

The most complicated thing was to produce a plate with guarantees of operation, but once this was obtained, programming could be relatively easy. We must also say that the programming language used then is not the same as we can find today on platforms such as Lego or the Arduino itself.

4.2 Present trends

While Lego has emerged as the standard of educational robotics, the affordable option for all budgets is the Arduino board.

The fact that Lego is so successful in this field, is undoubtedly due to the ease of assembly and the ease of its programming code. Therefore, this platform is suitable for students of very different ages, that is, from primary to university.

Even so, Arduino becomes the platform per excellence for robotics at many levels of education. For young people or university students, this platform is the right tool to develop and expand their knowledge of microcontroller programming or the culmination of mechatronic projects.

There are other options in the current market that are directed towards the field of robotics, such as the VEX platform, most commonly used in the field of competition or the small computer RASPBERRY PI where it also has something to say in terms of robotics.

Let's briefly discuss the most representative current platforms so far.

- **Lego WeDo/Mindstorm**

Lego is made up of a series of pieces of different shapes and sizes. With these you can create all kinds of Constructions, and robots too.
Lego, and specifically Mindstorm motivates users to build their own robots or mechatronic projects. The most common devices available to Lego are actuators (motors), ultrasonic sensors, colour sensors, motion sensors, infrared sensors, etc.
Its flexibility and the possibility of adding pieces to the acquired kits make Lego Mindstorm a very powerful tool for educational robotics.
Specifically, Lego WeDo, due to the ease of block programming, has become the tool per excellence for primary school students.

One of the positive characteristics of Lego, is the amount of material for teachers on its official website, which delivers a whole series of practices and projects for their classes.

The Lego Mindstorm has two versions of its brain or platform, that is, the EV3 and the NTX.
As an example, let's see the technical characteristics of the EV3

- LINUX Internal Operating System
- ARM9 microprocessor at 300 MHz
- RAM memory: 64 MB
- Flash Memory: 16 MB
- Screen resolution: 178x128 in black and white
- USB 2.0 communication
- MicroSD card up to 32 GB maximum.
- RJ12 ports for sensors and actuators (motors)
- Powered by 6 AA batteries or a rechargeable Li-ion battery

- **Arduino UNO**

Arduino UNO is the most popular of this family.
Arduino UNO is a card the size of a credit card equipped with an Atmega 328P microcontroller with a processing speed of 16 MHz.
Thanks to a series of input and output pins, we can connect a whole series of sensors, actuators, modules, shields and electronic components to create our projects.
Specifically, Arduino UNO has 14 digital input and output pins, 6 analogue input and output pins and a series of pins for its power supply and that of sensors, actuators and other components.
Of sensors and modules, for Arduino we can mention many, the most common are:

- Ultrasonic sensor
- Motion sensor or PIR
- Sound sensor
- Temperature sensor
- Humidity sensor
- Light sensor or LDR
- etc.

The programming language is a mixture between the programming languages C and C ++.

- **mBot**

The mBot is an educational robot that is having a lot of acceptance. It is a system of pieces with which can create different robots. The mBot is a basic robot but at the same time a very complete one because of the number of sensors that it incorporates in its own board.
It uses a modification of the Arduino board that receives the name of mCore.
In particular, the sensors and devices that it incorporates are:

- Light sensor (LDR)
- Speaker
- Two RGB LED diodes
- An IR receiver (Infrared)
- An IR emitter (Infrared)
- One button / push button
- An ultrasonic sensor
- Two DC or DC motors
- A line tracking sensor (Infrared)
- Bluetooth

The general specifications of the robot are:

- Plate: mCore based on Arduino UNO.
- Microcontroller: Atmega328
- Connections: 4 RJ25 ports, 2 special ports per to DC motors
- Robot feeding: 3.7V battery or 4 AA batteries
- Communication: Bluetooth or 2.4G
- Software: IDE (Development Interface) inspired by the famous Scratch programming language. Versions for Windows, Linux and Mac.

4.3 Future trends

Devices with a high Artificial Intelligence (AI) as Google, Amazon or Apple assistants and in some cases the "easy" programming of these open the doors to a new concept of robotics.
Devices such as *Leap Motion* or the *makey makey* together with the Bots generated to serve clients in web pages in a completely autonomous and virtual way, allow us to glimpse a future where robotics will have a very high weight.

5 Analysis of the consequences Robotics may have on the future job market in the EU

5.1 The need for students to be addressed toward robotics

Robotics, Mechatronics, Biotechnology, Big Data and mobile application development are the areas with the greatest demand for professionals, both now and in the coming years, according to a study prepared by the human resources company Randstad.
The constant evolution of technology and its application to various sectors is generating that among the most demanded profiles stand out specialties related to Industrial Engineering, Mechanics, Mechatronics, Electronics and Robotics.
Likewise, Randstad Professionals foresees a mismatch between the supply of the labour market and the needs of the companies, because while the need for STEM profiles (Science, Technology, Engineering & Mathematics) in the labour market grows at a rate of 14% per year, only 7% of students are enrolled in degrees directly related to these areas.

5.2 The presence of robotics in European industry

SPARC is the partnership for robotics in Europe to maintain and extend Europe's leadership in robotics. SPARC aims to make available European robots in factories, in the air, on land, under water, for agriculture, health, rescue services, and in many other applications in Europe which have an economic and societal impact.

5.2.1 Robotics has a tremendous impact

Robotics is on the verge of having a tremendous impact on the economy and our society.

Robots are known to save costs, to improve quality and working conditions, and to minimise resources and waste.

From today's €22bn worldwide revenues, robotics industries are set to achieve annual sales of between €50bn and €62bn by 2020.
In the field of industrial robotics, which is currently growing at 8 % p.a., Europe's share of the world market is about 32%. Here it will be important to find new applications outside the automotive sector.

Europe's share in the world service robotics market currently stands at 63% which is the result of Europe's excellence in interdisciplinary research in "intelligent robots" and a culture of cooperation between industry and academia.

However, the much larger impact comes from the effect robotics has upon the competitiveness of the manufacturing and service industries that use robotics systems and technologies, and upon the quality of life for citizens.

Figure 1. Robots picking pretzels from a conveyor belt.(Source ABB)

Industrial robots are not only good in the automotive industry. They have entered the food industry a few years ago.

A recent study by McKinsey estimates that the value of the application of advanced robotics in healthcare, manufacturing and services could have an annual economic impact of between $1.7 trillion and $4.5 trillion worldwide by 2025

5.2.2 The need for European action

In a globally competitive environment, Europe is not only competing against low-wage economies, but also highly automated economies and as the decade progresses robotics usage will increase around the world. In the competitiveness, productivity and sustainability battle, leadership in robotics technology will be the key differentiator.

Robotics markets are evolving quickly and robotics will be a key source of competitive advantage and a means for tackling societal challenges and to excel in science. To maintain and build its position, Europe needs to take concerted action. European-wide action is required to take advantage of regional and national strengths in the core multi-disciplinary competencies of robotics and build critical mass, particularly with regard to efficient supply chains that will be vital for the delivery of cost-effective products and services.

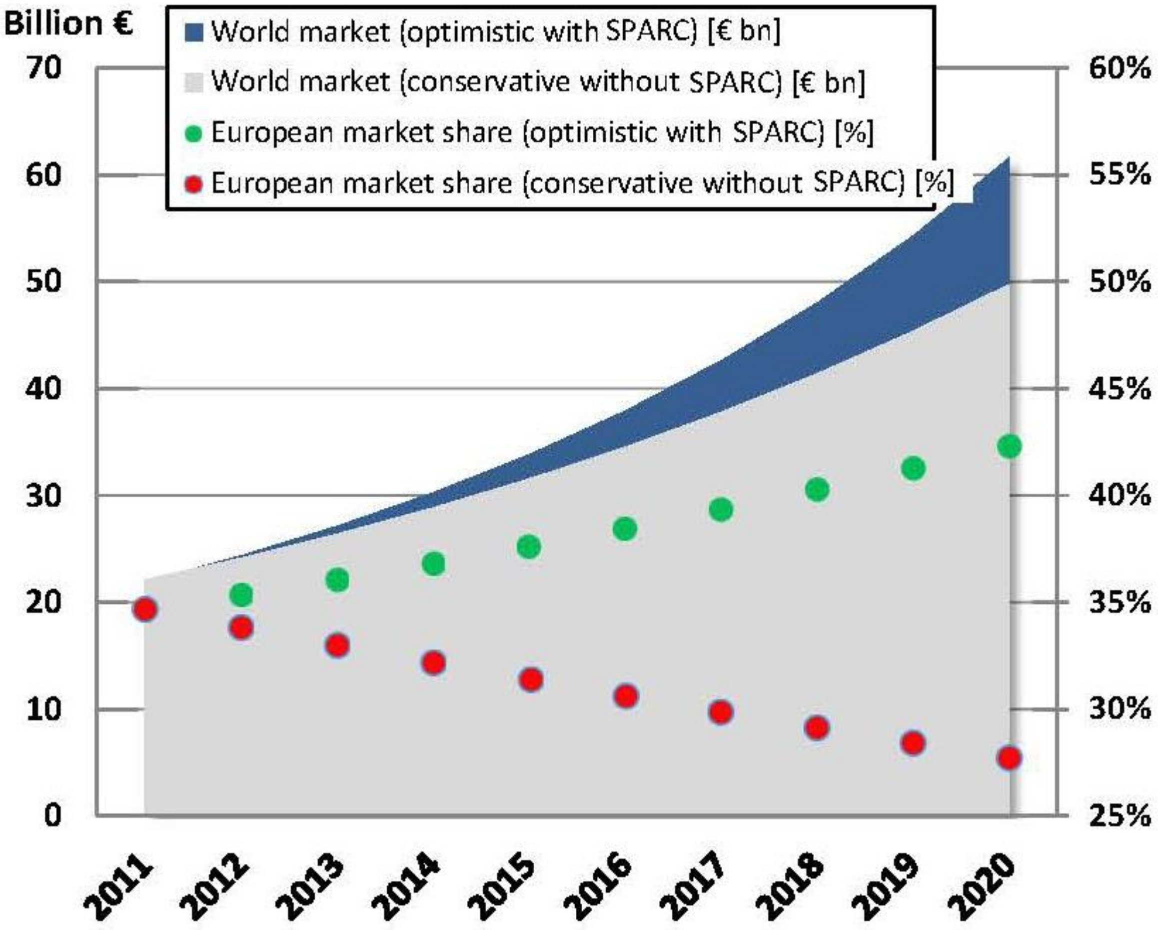

Figure 2. European market estimation. (Source: https://www.eu-robotics.net/sparc/about/robotics-in-europe/index.html)

Estimates on the world robotics market developments and reachable European market shares. The effects of SPARC are noticeable in a significant uplift of the European market share (plus 14%) and a resulting additional turnover of approximately €44bn (cumulated over years 2014-2020). Growth rates and market shares are cumulated for the entire robotics domain from industrial, professional (without defence-related applications) and domestic service robotics.

6 Conclusions

Robotics is one of the components with the greatest strength to captivate and motivate students today. Robotics is also considered one of the fundamental pillars of Direction 4.0 project.
It is of great importance to ensure greater interest and dedication for technology and for the science of our young people in the face of a technological future not too distant.
The contents in the network, new applications, the increase of all kinds of robots and artificial intelligence among other technologies are presented as protagonists in the coming decades for a highly digitalized society, where the main tools in learning is a digital one.
In short, robotics has a highly motivational component for our students, which can be translated into a growing interest in science and technology for future engineers and scientists who will be responsible for providing content to a highly technological society.

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Cybersecurity for Industry 4.0

By Krzysztof Ciapala

The fourth industrial revolution brings many challenges, among them ensuring high level of security for hyper-connected smart devices, robots, sensors and vast amounts of data. Nick-named cybersecurity, it is extremely important and in many cases underestimated component of Industry 4.0. One of the main features of Industry 4.0 is that it is smart, it can learn nearly in real-time and react to changes in its environment. To be able to achieve that, the requirements for communication means are enormous in terms of amounts of data sent, response time, security and so on. Cyberattacks directed towards such infrastructure can have far more extensive – and possibly dangerous effects than ever before.

Manufacturers and their supply networks might not be ready for such challenges and risks. The cybersecurity in Industry 4.0 requires in many cases new approaches and security strategies devised throughout the organization and it's inter-connected systems. Possible disruption via cyberattack on Industry 4.0 factory could cause much more losses than ever before. Cybersecurity is not a need, it is a crucial requirement for implementing Industry 4.0 systems.

Subjects Required for a Career in this area:

GENERAL SCIENCE	⬜	⬜	⬜	⬜	⬜
ICT	⬜	⬜	⬜	⬜	⬜
MATHEMATICS	⬜	⬜	⬜	⬜	⬜
PHYSICS	⬜	⬜	🟩	🟩	🟩
BIOLOGY	🟩	🟩	🟩	🟩	🟩
CHEMISTRY	🟩	🟩	🟩	🟩	🟩

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1 Introduction

In the first few years of this millennium, IT security was more about protecting people, computers and organizations from traditional bad-ware threats such as malware, viruses, ransomware social engineering attacks, website hacking, hacktivism, etc.

In the last few years, however, we have witnessed increased sophistication and intensity in cyber-attacks, which are now oriented towards financial crime, industrial espionage and have even targeted governments and other critical infrastructures.

In 2009, a malware manipulated the speed of centrifuges in a nuclear enrichment plant, causing them to spin completely out of control, to the point of destruction. This malware, now known as Stuxnet[1], was introduced into isolated networks via flash drives, and it autonomously spread across production networks. Stuxnet's sophistication serves as a prominent example of cyberattack potential as weapons in the world of connected physical factories. While there are now analysis that Stuxnet was a result of international espionage operation and malware source code was never fully revealed, it is only sensible to assume that it wasn't the last attack on physical infrastructure.

In the era of Industry 4.0, the organizations are hyperconnected, meaning that network connectivity is present literally everywhere. This exposes a very lucrative target for the cyber criminals who might be able to find many relatively easy and insecure entry points into networks and devices.

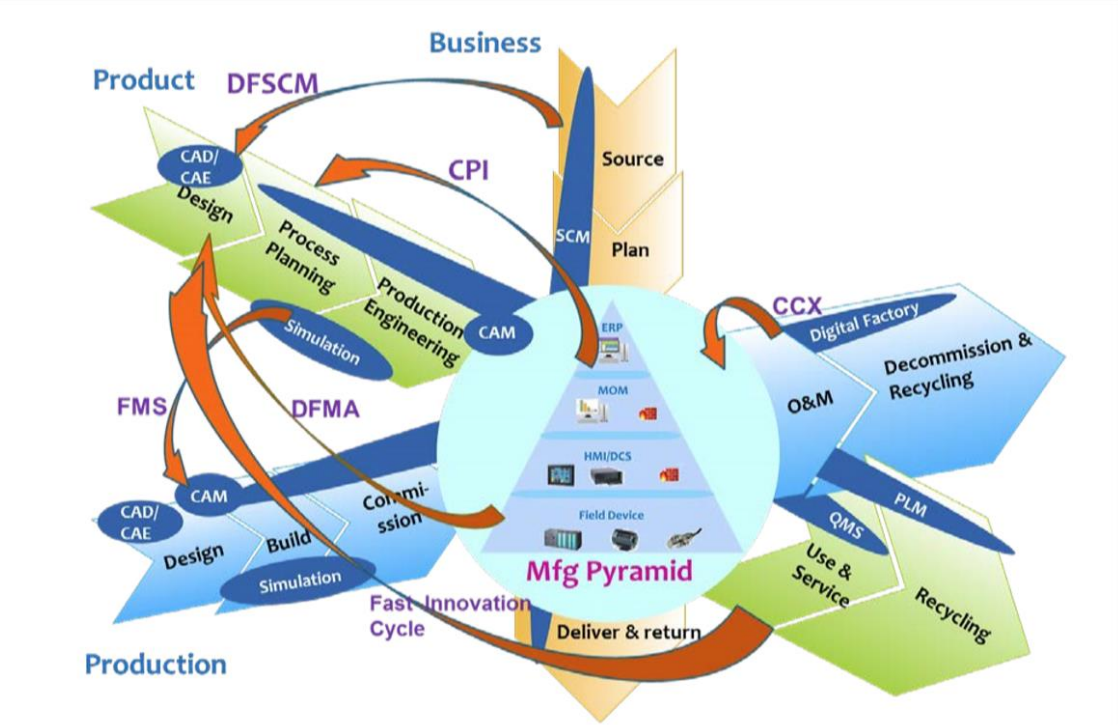

Figure 1 Smart Manufacture Ecosystem. Colours represent: product (green), production system (blue) and business (orange). Source: NIST

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[1] https://www.csoonline.com/article/3218104/malware/what-is-stuxnet-who-created-it-and-how-does-it-work.html

As new threats, techniques and attack vectors emerge, the focus of cybersecurity is slowly but surely shifting away from classic perimeter based approach with segmented and firewalled solutions to a 360 degree orientation, where various types of network security systems are dynamically working together and exchanging information. Examples of such systems could be Network Access Control, Intrusion Detection Systems, User & Entity Behaviour Analytics and others.

It is therefore required to protect hyperconnected systems, network and data of this generation from damages and unauthorized access. This approach is accepted by the CEOs of Fortune 500 companies, who identify the pace of technological change and cybersecurity[2] as the biggest challenges they face today. Cybersecurity should no longer be viewed as a function of IT or information security alone. Instead, it needs to form an integral part of culture and strategy of the organization aiming for Industry 4.0. It should be reflected in each and every part of the organization, right from the strategy to the training and behaviour of an individual employee. Such an integrated cybersecurity vision aligns business functions of the organizations with needs of the stakeholders and becomes a more acceptable strategy.

2 The anatomy of Industry 4.0

Even today, and in fairly traditional models, medium to large factories are fairly complex. There is an immense amount of ICT required, from design and prototyping phases to managing assets, stocks, finances, HR, controlling and many, many more.

With Industry 4.0, things get really hard, since pretty much everything needs to be connected to the network and many communication processes are machine-to-machine, but also amounts of data gathered and processed raise exponentially.

Moreover, essential component of Industry 4.0 is connectivity with outside networks, e.g. supply networks, digital supply networks, so called value chains, remote vendors, etc.

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[2] http://fortune.com/2017/06/08/fortune-500-ceos-survey-ai/

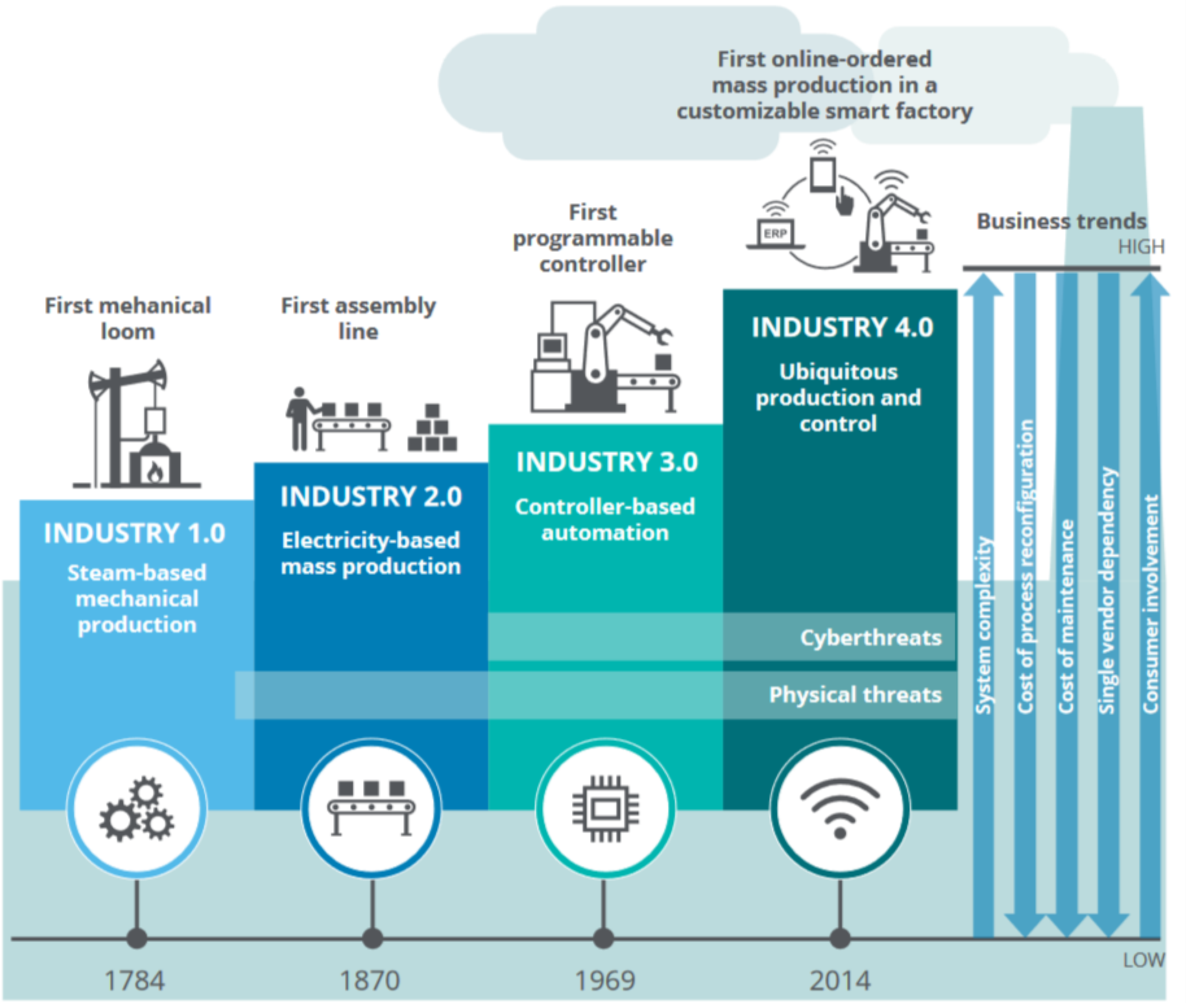

Figure 2 Evolution of cyber and physical threats for each industrial evolution. Source: Deloitte

Industry 4.0 and resulting Smart Manufacturing as next-generation manufacturing process utilizes several complex new technologies (non-exhaustive list):

- IoT end devices – Industrial Internet of Things devices, the core of Industry 4.0 which have various capabilities, such as sensing, actuating, storing and/or processing data and that exchange data over the network. This might include various robotics devices and drones,
- Machine-to-machine (M2M) communication - technologies that enable direct communication between devices in the network without human interaction,
- Big data analytics - process of examining and analysing vast amounts of various types of data generated in real time by smart sensors, devices, log files, video and audio feeds,
- Advanced Robotics - advanced industrial robots designed to performs complex tasks with smart capabilities, such as the ability to learn from mistakes and errors, improve their performance over time and be aware of the surroundings,
- Artificial Intelligence (AI) - algorithms that enable computers and various digital machines to perform tasks typically associated with intelligent human beings,

- Machine Learning (ML) - algorithms that enable computers to act and improve their ability to predict without being explicitly programmed to do so,
- Predictive Maintenance - solutions that monitor the condition of various equipment predicting when the failure may occur, also informing when the maintenance will became necessary,
- Real time monitoring - set of technologies that enable collection and aggregation of security data from system components and monitoring and analysis of events that occur in the network,
- Advanced loss analytics - methods for analysing various types of losses that may occur in a Smart Manufacturing environment with the objective to help analyse cases and eliminate or reduce them,
- Cloud Computing – usually, but not always, remote computing resources enabling access to shared assets like networks, servers, storage and applications with reduced IT management overhead,
- Additive Manufacturing – also known as 3D printing, technologies that enable the creation of 3D objects adding material via specialized printers, e.g. rapid prototyping,
- Augmented reality – set of technologies that apply computer generated images to real world environment via special glasses or other computer displays, meant for various tasks, e.g. to improve the efficiency of manual assembly tasks.

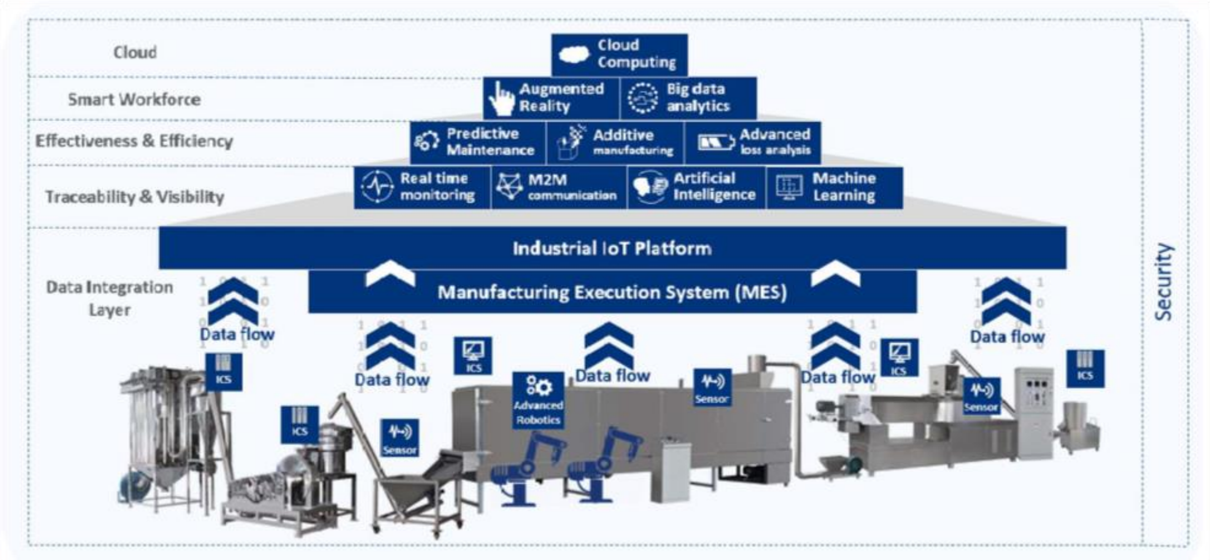

Figure 3 Industry 4.0 and Smart Manufacturing capabilities and layers

All off these classes of devices and technologies are meant to be interconnected, providing very large surface of possible cyber-threats and attacks.

As seen above, Industry 4.0 presents completely new level of complexity, even comparing to today’s factories. For the purpose of classification and easier understanding, various experts working in ENISA (European Union Agency For Network and Information Security) have identified the following areas:

- ICS (Industrial Control Systems) – this group consists of control systems, such as SCADA (supervisory control and data acquisition) and DCS (distributed control systems), as well as other control system elements, such as PLCs (programmable logic controllers) and HMIs (human machine interfaces). ICSes are not new, they are being used currently within many industrial settings to control e.g. manufacturing processes and keep them within pre-established parameters, like temperature, given fluid flow or pressure, etc. These systems typically also have built in utilities for diagnostics and maintenance,

- IIoT End Devices – new class of devices that have various capabilities, such as sensing, actuating, storing and/or processing information. What's new and distinguishes them from traditional devices like these used in industrial applications for years is the fact that IIoT End Devices are connected and exchange data over the network. In Smart Manufacturing environment, IIoT devices can send large amounts of new types of data in real-time and contribute to controlling and streamlining production,
- Manufacturing and business processes – this group consists of activities that lead to achieving a certain goal, in this case manufacturing a final product from raw or pre-processed materials or components. These processes include technological procedures that may vary greatly depending on the characteristics of the company, as well as organisational processes,
- Artificial Intelligence and Machine Learning – due to the collection of vast amounts of data from industrial processes, various ML and AI solutions are used for analysis, which otherwise would be not feasible. Artificial Intelligence transforms manufacturing by making it easily adaptable without having to spend long hours to reprogram industrial robots, enabling predictive maintenance and increasing flexibility[3],
- Control systems communication networks and their components – this group includes the connectivity networks, devices and industrial protocols. They have a crucial role in a Smart Manufacturing system since they allow various components to exchange data between devices and also between layers of management. Large array of devices might be used here, depending on the requirements, size, data speeds and so on.

3 Challenges from the cybersecurity point of view

Industry 4.0 and Smart Manufacturing present numerous benefits[4] over traditional infrastructure, but also significant challenges. In recent survey, 65% of companies expressed their concern over cybersecurity and implementing Industry 4.0 in practice.

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[3] TOPBOTS (2017) "Future Factories: How AI enables smart manufacturing":

[4] https://www.pwc.com/gx/en/industries/industrial-manufacturing/publications/digital-factories-2020.html

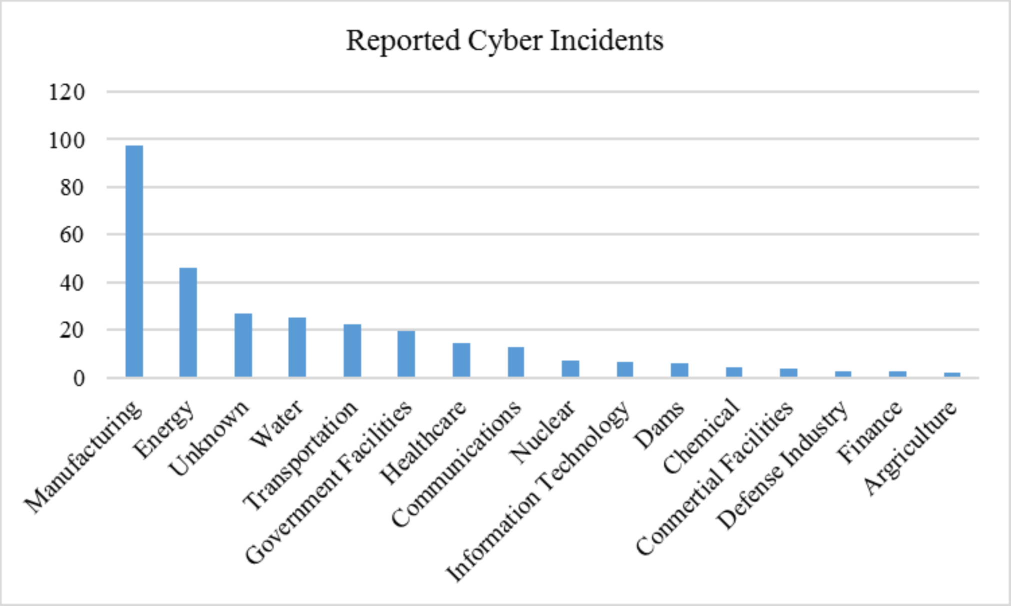

Figure 4 US reported cyber incidents by Infrastructure sector. Source: IoT Security Foundation

Most industrial environments were not designed with high cybersecurity in mind. Manufacturing systems are now moving towards cyber-physical systems, where any vulnerabilities could be detected and exploited by malicious individuals.

ENISA identified several areas with their the generic security challenges, some of them are presented below.

- Vulnerable components – with the fourth industrial revolution, IoT devices became connected – and it means billions devices globally. It poses a massive challenge to provide secure connectivity for these devices. They need to be evaluated against typical IT-like vulnerabilities and should be a subject in a security policies – what never before was needed. In industrial environments this may pose a considerable challenge since most systems of this type were not designed with cybersecurity in mind and thus vulnerabilities in this hardware are becoming more and more common[5].
- Management of processes – in addition to the large attack surface in terms of connected devices, a large number of complex processes involved in Smart Manufacturing needs to be considered. Management of processes with cybersecurity in mind poses a challenge for Industry 4.0 companies, especially since functionality and production efficiency are usually having a higher priority than cybersecurity.
- IT/OT convergence – industrial control systems used to be isolated from the rest of data networks. Now, however, the incorporation of IT components in the ICS domain become common. Connecting with IT network enabled organisations to simplify the management of complex environments but also introduced new security risks. The factors include insecure network connections (internal and external), technologies

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[5] https://www.ptsecurity.com/upload/corporate/ww-en/analytics/ICS-Security-2017-eng.pdf

with known vulnerabilities which could introduce previously unknown risks into the OT environment, and insufficient understanding of requirements for ICS systems.

Figure 5 LBR iiwa by Kuka – world's first sensitive robot approved for Human-Robot collaborative work. Photo: Kuka

- Supply chain complexity – manufacturers are very rarely able to produce every part of the product itself and usually need to rely on external suppliers' components. Developing technologically advanced products results in an extremely complex supply chain with a large number of people and organisations involved, thereby making it highly demanding in terms of management and security.
- Legacy industrial control systems – legacy hardware is a very significant barrier to adoption of the IIoT by over a third of the respondents according to a recent survey[6]. These systems can be extremely expensive and difficult to integrate, so often manufacturers build new systems on top of legacy systems, and this could result in outdated base systems and contain unknown vulnerabilities that have been inactive for years. Adding new IIoT devices to outdated hardware raises concerns that it may allow attackers to find new ways to compromise systems.
- Insecure protocols – manufacturing components often communicate over private industrial networks using specific protocols. Quite often, these protocols were never meant to be used in open networks and they may not contain even basic security features. According to a recent report, 4 of the 5 least secure protocols are ICS specific[7].
- Human factors – adopting entirely new technologies means that all employees have to work with new types of data, networks and systems. Several leading security

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[6] World Economic Forum (2015) "Industrial Internet of Things: Unleashing the Potential of Connected Products and Services"

[7] https://www.synopsys.com/content/dam/synopsys/sig-assets/reports/state-of-fuzzing-2017.pdf

companies and organizations agree that human factor is most problematic element of highly secured systems.
- Safety aspects – the presence of highly autonomous IIoT devices that act on the physical world makes safety aspects very relevant in IoT and Smart Manufacturing. Security policies for working in close proximity to e.g. actuators are extremely important.
- Security updates – applying security (or in fact, any) updates to IoT infrastructure is extremely challenging, since in many cases these devices do not have typical user interfaces. Securing such systems is in itself a daunting task, especially considering Over-The-Air updates. In OT (Operational Technology) environments in particular, applying updates may be challenging since this operation needs to be scheduled and performed during downtime.

4 Security measures towards Industry 4.0

From the previous chapters, we showed clearly that security in general and cybersecurity are very important points for all manufacturers and industries which are or will be implementing Industry 4.0 and Smart Factories.

Since the topic itself is very complex, several models and approaches have been developed, together with taxonomy of industrial assets and breakdown of foreseen types of vulnerabilities.
Going into details is well beyond the scope of this material and probably is more appropriate for technology developers and systems integrators.

It is important however to know that three main areas were identified during the research and although the list is not complete (and never will be, as new technologies will emerge and new security risks will be identified) it gives a broad overview of processes involved.

Policies:
- Security by design
- Privacy by design
- Asset management
- Risk and threat management

Organizational practices:
- Endpoints lifecycle
- Security architecture
- Incident handling
- Vulnerability management
- Training and awareness
- Third party management

Technical practices
- Trust and integrity management
- Cloud security

- Business continuity and recovery
- Machine-to-machine security
- Data protection
- Software and firmware updates
- Access control
- Networks, protocols and encryption
- Monitoring and auditing
- Configuration management

In the following pages we are going to explore these areas, to the point which should be beneficial for this publication.

4.1 Security policies

The first part refers to policies and procedures that should be established within organisations as a core documentation and guidance. This document should be consulted with wide area of users, not only IT department, as it concerns much wider range of users, processes and equipment. Additionally, it should contain policies related to personal data protection, as required by the GDPR[8].

- Security by design - security should be considered from the early stages of the product development. IoT security should be considered as a cycle rather than process and should be repeated on predefined intervals. Security features should be implemented whenever possible on the end devices themselves rather than only on network level. All connected devices, even very limited in features, should be included in the IAM (Identity and Access Management) system. Risk and threat analysis should be performed, including external security and auditing experts. Policy documentation should be reviewed and accepted by management staff and recognized company-wide.

- Privacy by design - given that factory is based in EU, GDPR should be the single most important point. In fact, it is required by GDPR to include privacy at design stages. Effectively, private data should be collected only to minimum required level and whenever possible replaced by identifiers, certificates or other means ensuring least impact on employees, assets and supply chains. Special consideration should be given to HR departments, which collect personal data by default. This data should be especially well protected and steps should be taken to ensure only authorized individuals could access it – and only when they need it. Additional steps should be taken, like end-to-end data encryption and advanced logon systems using tokens or equivalent, as potential data leakage could have serious implications, also financial, for the whole organization.

- Asset management – this area concerns keeping all the assets – especially network connected devices, known, identifiable and discoverable. Asset management tools should be used, with secure central inventory, regularly updated, checked and

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[8] General Data Protection Regulation, https://eur-lex.europa.eu/eli/reg/2016/679/2016-05-04

maintained. Especially all actions related to removal and replacement should be strictly monitored and acknowledged, as so called “rogue device”[9] could be a very serious threat to the whole network – or at least network segment.

- Risk and threat management – complex and difficult group, which should focus on assessing risks and possible threats – and counteracting them at policy level. Risk analysis should be performed at annual intervals and results should be aligned with other relevant policies. Specifically, risk assessment analysis should test established security policies for their effectiveness, given changing external conditions. Team working on this subject should be well trained in cybersecurity and especially with threat management. External bodies like e.g. CERT should be considered for cooperation and information sharing, as they provide wider outlook of current and discovered security threats

4.2 Organizational practices

These practices cover several organisational rules, practices and responsibilities which should be established and followed, towards employees and external contractors, in order to properly handle cybersecurity incidents and manage vulnerabilities.

- Endpoints lifecycle – this is relevant to all assets, end devices and infrastructure, at all stages, from the procurement till end-of-life. Special consideration should be given to end devices which store and process data – to ensure proper procedures for data erasure and destruction.

- Security architecture – this is area where it should be decided – and designed, at organisation level about the all responsibilities and roles related to security. Industry standards like IEC 62443-2-1:2010 Establishing an industrial automation and control system security program and IEC 62443-3-3:2013 System security requirements and security levels should be followed – but not limited to.

- Incident handling – this in principle should be a set of documents related to handling all the security related incidents. This can’t be ad hoc, but rather procedural approach, defining how to handle specific incidents, identification of affected assets, vulnerabilities, escalation and notification as appropriate. In larger organisations, it is often a specialised team of OT and IT experts working together.

- Vulnerability management – this concerns process and risk analysis, penetration testing and addressing vulnerabilities, typically with process of updates – or in some cases, removal if the risk would be deemed too great and no solution could be found. Since the process can be potentially disruptive for industrial activity, this should be well planned in advance and tested in controlled environment before conducting full-scale deployment.

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[9] https://www.iso.org/standard/54533.html

- Training and awareness – possible one of the biggest challenges in large organization, as human factor is often quoted as of the highest risk to cybersecurity. Security training should be continuous, regular and verifiable. All new employees need to be trained, but in the era of connected Industry 4.0 – also third party suppliers and cooperation networks.

- Third party management – as pointed above, third party access is needed, but at the same time it presents serious security concerns. At very least, very strict and granular access controls should be implemented, granting third parties access to only what is required, preferably on-demand and for specific purpose. All accesses should be audited in form of log files, with enough information to track back all the activities. Security aspects of third party access should be defined in partnership agreements.

4.3 Technical practices

Apart from organizational and policy levels, significant amount of work needs to be implemented at strictly technical level. This goes well beyond scope of this document as it is highly technical area, we'll only mention some aspects, without going into details.

- Trust and integrity management – at base level, all endpoint devices should be authorised via certificates and Public Key Infrastructure environment and exchange data only with authorised and whitelisted devices. Data encryption in transit should be used whenever possible.

- Cloud security – complex aspect of choosing relevant computing model (private, hybrid, cloud), which involves choosing the right provider and establishing which business processes needs to run in which model.

- Business continuity and recovery – security measures related to incidents and disruption, in correlation to potential costs involved with them.

- Machine-to-machine security – means of ensuring secure communication between machines. This involves special authentication measures and secure storage of cryptographic keys and detection of possible attacks.

- Data protection – related first of all to confidential data. Encryption at-rest and in-transit is practically a requirement for highly confidential data, as well as role-based access rules to the data, based on key management.

- Software and firmware updates – this process involves verification, testing and installation of software updates, also known as patches. In industrial environment, it is critical to test possible side effects, as well as verify authenticity and integrity.

- Access control – various security measures related to remote access, physical access, authentication and privileges. Whenever possible, multi-factor authentication should be utilized, strong passwords enforced and accounts lockouts should be implemented to avoid brute-force and dictionary attacks.

- Networks, protocols and encryption – it is a very complex subject, as designing network infrastructure for large industrial organisation is extremely challenging. In principle, large network should be divided into organizational and security zones (segments), network should include monitoring and management using security-proven protocols (e.g. SNMP v1.3 with TLS). IDS (Intrusion Detection Systems) should be utilized as well and all unused and unneeded services and protocols should be disabled. The general idea when designing secure network infrastructure should be – only needed and verified protocols, destinations and devices should be allowed.

- Monitoring and auditing – related to previous point, a specialized NMS (Network Management System) as well as SIEM-class (Security Information and Event Management systems should be implemented and utilized. Regular log analysis should be conducted, as they allow to detect possible malfuctions and threats.

- Configuration management – essentially it is change management. There should be baseline security configuration established for different types of assets and followed, and all changes should be documented. The baseline should be regularly reviewed and updated as needed – because of condition, hardware or organizational change.

5 Conclusion

As shown on the above pages, cybersecurity in Industry 4.0 organization is extremely complex. It involves numerous classes of devices, human factors and external collaborators. Keeping such connected infrastructure requires sizable investments and highly trained and motivated staff.

In the scope of this document, we tried to show some aspects involved in Industry 4.0 technology, to raise the awareness and give a broader view, not necessarily to conduct a de-facto training, since that is clearly beyond the scope of these materials.

6 Glossary

CRM Customer Relationship Management

CERT Computer Emergency Readiness Team

(D) **DoS** (Distributed) Denial of Service

DCS Distributed Control System

DRP Disaster Recovery Plan

ERP Enterprise Resource Planning

ESS Executive Support System

HMI Human Machine Interface

ICS Industrial Control System

IDS Intrusion Detection System

IPS Intrusion Prevention System

ISAC Information Sharing and Analysis Centre

M2M Machine to Machine

MES Manufacturing Execution System

ML Machine Learning

PLC Programmable Logic Controller

QC Quality Control

RTU Remote Terminal Unit

SCADA Supervisory Control and Data Acquisition

SIEM Security Information and Event Management

SIS Safety Instrumented System

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Methodology to create a workshop

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This methodology presents some ideas about how motivate students to take part in an extracurricular training course on technological issues.

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1 Choosing the right platform:

This will depend on the age of the students and the learning outcomes we want to teach

1.1 According to the students' age

Depending on the age we will choose one platform or another
It is better to choose more than one platform and to check which is more suitable to the group

1.2 According to difficulty

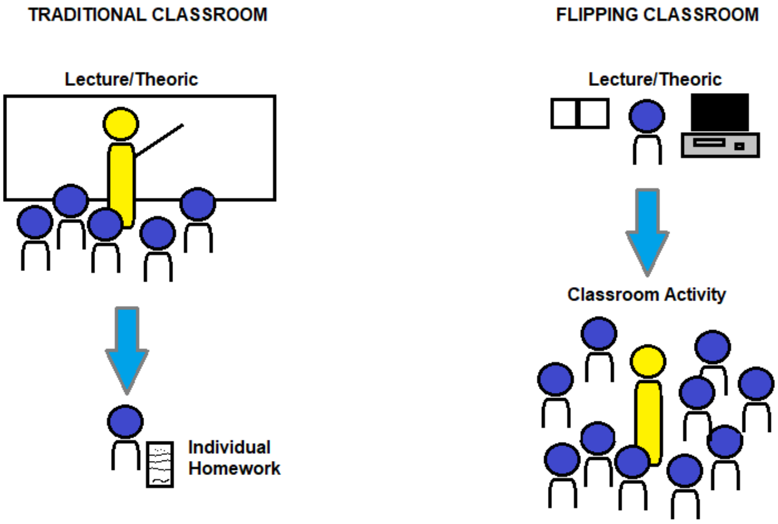
Platforms may look very appealing but it is important to check which are better according to age

1.3 According to budget

Important to find a balance between budget and quality.

2 Teaching method

2.1 Flipped method.



Students watch a film or read documents at home or before the class starts. When in class the student will discuss with his classmates and teacher his /her doubts

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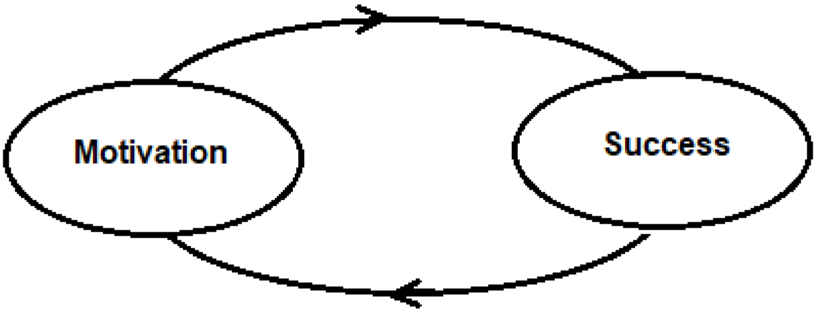
Applying flipped methodology critical thinking is developed and students feel motivated and feel classes as a challenge



2.2 Traditional learning method.

Traditional class where students are led by the teacher from the very beginning by following the training prepared by the teacher.

It is recommended to create appealing materials where media resources are combined.

2.3 Competition

A competition can be a challenge that motivates students.

Ideally all students should get a prize so they do not loose motivation

Prizes may be material devices that can be used in future training.

2.4 Certificate

Students feel motivated if at the end of the training a Certification is issued.
This certificate will show the hours and skills acquired.

STUCOM
CENTRE D'ESTUDIS

CERTIFICAT

STUCOM ROBOTICS

STUCOM CENTRE D'ESTUDIS CERTIFICA QUE

Daniel Hida Hida

HA ASSOLIT SATISFACTÒRIAMENT ELS OBJECTIUS DEL CURS

INICIACIÓ A LA ROBÒTICA

AMB UNA DURADA DE 22 HORES

PEDRO PORCUNA, COORDINADOR DEL CURS

INTERESSAT

BARCELONA, 17 DE JULIOL DE 2017

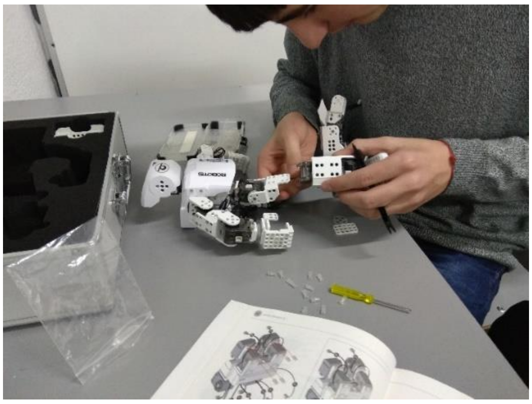
3 How to motivate students to join our training course?

3.1 Motivating videos

A short motivating video which combines appealing pictures, results, methods and music is essential to make students feel what they will do.

3.2 Projects already finished

Showing projects that have been made by other students will show participants that they will be able to do the same



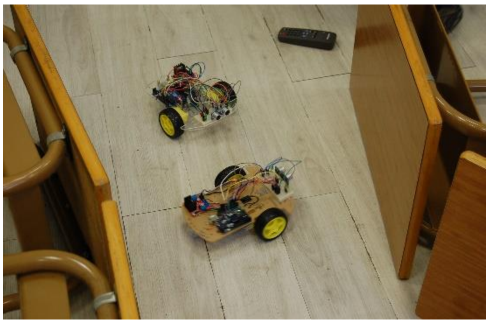
3.3 Attending to fairs related to the training

Visiting fairs related to the Project can help them to see how important is to take part in a specific training

3.4 Internal competition among students and exhibition of results at school

As mentioned before an internal competition every 3 months could motivate students a lot.

Results of the competition and outputs can be shown at school so students who have not attended the training can feel motivated to join the course



3.5 Competition with other schools

If we know other schools where the same topic is taught it could be interesting to contact them and to create a competition where all students compete.

This will not only motivate students but also the teachers who will stimulate their students to get the best results.

Students can write the guidelines of the competition this will make the contest fair and appealing for them

4 Teacher’s role in the classroom

The teacher clarifies doubts that may appear about the concepts studied.

The use by the teacher of the "flipped " method should not make the teacher forget the resolution of possible problems and / or doubts of the students with the correct understanding of the concepts studied.

4.1 “Learning by doing”

Students must put into practice the knowledge acquired.
They are provided with the theoretical material, the statement of a practical activity that will finalize the subject to be studied.

This statement is about a problem that they have to solve with the material they have and which the teacher has explained.

The activity is not considered successful until the student shows the teacher the correct functioning of what is developing and therefore the correct solution to the problem or proposed challenge.

At times, it is also beneficial for the student to discuss and share with the group and solutions, reinforcing the students’ self confidence

Creating solutions to a proposed problem in a non-theoretical way motivates students to move forward with subsequent challenges.

4.2 Team work

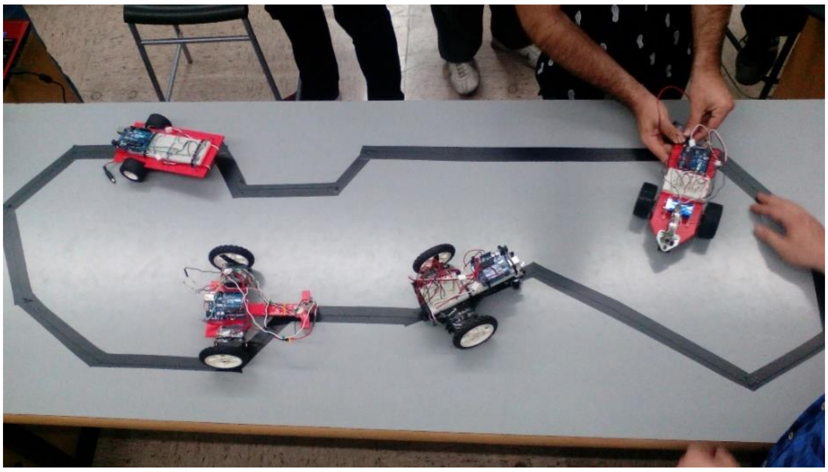
Teamwork is essential.
The teacher must determine if the creation of some groups can benefit the student to reach the course objectives.

The teacher must also decide if the groups should be integrated by two or three students. Possibly, two or three students per group is a suitable amount. So that the students themselves do not fall into apathy or demotivation due to causes of leadership within the group, the teacher must assign a role to each of the group members, in this way it is ensured that each member has its own task

4.3 Final challenge

Through all the knowledge acquired during the course, students must design, create and present a kind of final project.

The project can be a free project restricted only by a few rules, such as the material to be used or it can be totally guided, that is, all students or groups must do the same project with small design modifications.



5 Final feedback

Once the course has finished, it is time to find out students' opinion
A simple survey with a few questions can give us a clear idea of the opinion about the course.
Questions can be written (students are very likely not to write too much) or questions where students must choose a value to score the question.

We can include questions such as:
- What do you think of the training?
- Would you recommend this training to friends and acquaintances?

The results help to improve future editions of the course. Adding, changing or deleting certain points in the programming of this.

6 Renewing the course

An issue to assess each time you decide to teach a course, especially of a technological nature, is the expiration of the content of it.
Software technologies and versions are advancing at breakneck speed in a society increasingly digitalized and dependent on technology, so it is necessary to ask if the knowledge that is being taught is part of the past or is still current enough as to be a reason to impart them.

The teacher must know how to modernize or sophisticate the content, expanding it, modifying it or renewing it completely.

Remember that the objective of a course of these characteristics is to immerse, involve and motivate the student to feel interest and passion for science and technology.