A FUTURE FORETASTE: SHIPBUILDING INDUSTRIAL TENDENCIES

(DOI No: 10.3940/rina.ijme.2020.a4.649)

R Pérez Fernandez, and **E Péter Cosma**, SENER, Madrid, Spain

KEY DATES: Submitted: 07/06/2020 Final acceptance: 04/11/2020 Published: 04/12/2020

SUMMARY

We are living a continuous and fast technology evolution, maybe this evolution goes faster than our capacity to assimilate what we can do with it, but the potential is clear and the future will be for those who identifies the right technology with the right application. The way we work with Computer Aided Design (CAD) tools is also changing thanks to the ubiquitous access to information and the different hardware available to exploit that information: Augmented Reality, Virtual Reality or Mixed Reality. Not only the way we work, but also the way we interact with CAD tools is changing, with technologies like natural language processes that allows direct conversation with the applications. The concepts that are absolutely clear from now to the future in shipbuilding are the use of Data Centric models and the concept of Digital Twin. Both provide a real and effective synchronization between what we design and what we construct, by covering the complete life cycle of the product, thanks to technologies like the Internet of Things (IoT) and Radio Frequency IDentification (RFID). Nowadays it is unimaginable to work without using CAD in shipbuilding: ease of design with design rules embedded, speed of design, and the use and reuse of information. It is expected that in the future CAD tools will advance further and allow greater information management through further improvements. The paper presents several scenarios with improvements likely to occur the next few years. Some of these improvements may seem unrealistic in the short term, but reality often exceeds expectations in any field, and probably more so with technology.

NOMENCLATURE

AGV	Automated Guided Vehicles
AI	Artificial Intelligence
AR	Augmented Reality
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
CFRP	Carbon Fibre-Reinforced Polymer
DARPA	Defence Adv. Research Proj. Agency
DMLS	Direct Metal Laser Sintering
GPS	Global Positioning System
IoT	Internet of Things
JTAG	Joint Test Action Group
MR	Mixed Reality
PSoC	Programmable System on Chip
P2P	Peer to Peer
P&I	Piping & Instrumentation
RF	Radio Frequency
RFID	Radio Frequency IDentification
RPA	Robotic Process Automation
R&D&I	Research & Development & Innovation
SLS	Selective Laser Sintering
SDV	Self-Driving vehicles
TWT	Target Wake Time
UWB	Ultra-Wide Band
VR	Virtual Reality
W3C	World Wide Web Consortium

1. WHAT IS INDUSTRY 4.0

The Fourth Industrial Revolution takes the digitalization of industrial practises to an innovative level by presenting custom-made and adaptable mass manufacture technologies. In other words, machines will work autonomously, or collaborate with us producing a customer-oriented fabrication discipline that continuously works on sustaining itself. The machine rather converts a self-sufficient thing capable to gather or accumulate data, evaluate it, and guide upon it. This becomes conceivable by presenting self-cognition, self-optimization and self-customization into the industry. The manufacturers will be able to speak with workstations and computers rather than control or operate them. All of this will be possible through Artificial Intelligence (AI) or Internet of Things (IoT) for example, but there are many others technologies, which can be applied to a Computer Aided Design (CAD) System, included in, or as an integrated surrounding solution, or as information producers for the evolutive design process.

Figure 1: Related Industry 4.0 Technologies in a Shipbuilding CAD environment (Benayas-Ayuso and Pérez, 2019)

Many of the technologies shown in Figure 1 are not new, even in our century. For example AI, term coined in 1956 in the Dartmouth conference. Or the IoT concept, which it was born in the research centre Auto ID in MIT abound 1999 in research for realizing the object identification using radio frequency, Radio Frequency Identification (RFID). However, for first time we are in position to improve our way of work applying the Industry 4.0 in its entire widening.

2. INTERNET OF THINGS. THE "THINGS" CAN TALK WITH US

2.1 IoT OVERVIEW

IoT is the core element, we could say that digital transformation is being driven by IoT.

The investment in IoT worldwide reached US$ 745 billion last 2019 vs US$ 646 billion spent in 2018, which means an increase of 15.4% according to consultant company IDC data (see Figure 2). The economic effects of the COVID-19 pandemic have significantly influenced global spending on the IoT in 2020; however, it is foreseen that investment in IoT will grow annually to the rate already mentioned within the period 2017-2022 and thus, will surpass the barrier of US$ 1 trillion by 2022.

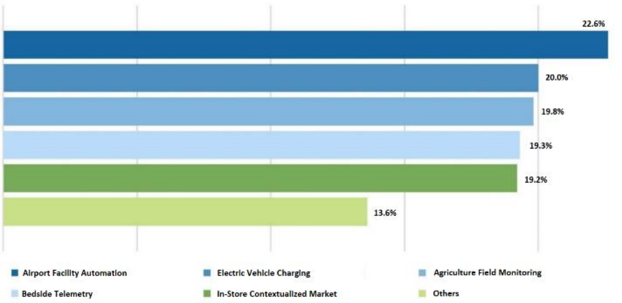

Figure 2: IoT use cases that are expected to deliver the fastest spending growth over the 2017-2022 forecast period worldwide (IDC, 2018a)

Which are the industries that invest more money in this type of technology and whose objectives they aim?.

- Discrete manufacturing (US$ 119,000 million): companies expect to have improvements in manufacturing processes and in the management of the productive actives by using this technology.
- Manufacturing (US$ 78,000 million).
- Transport (US$ 71,000 million): main use of this technology is to monitor the load and fleet management.
- Public services (US$ 61,000 million): main investment is focused towards intelligent network systems of gas, electricity and water for optimization of these resources.

At domestic level, the use of IoT is experiencing a strong thrust, and this is the area in which the growth is more significant. This means that IoT technology is not only absorbed by Industrial area, but day by day is more present in our lives, concerning home automation-automation and control of home processes for comfort purposes and also new possibilities that this technology provides when applied in our vehicles.

IoT means hardware as well, and along 2019 it is estimated that will have an expense of US$ 250,000 million being US$ 200,000 million the investment foreseen in modules/sensors purchases.

If we consider countries, the investment in IoT is headed by United States and China with US$ 194,000 million and US$ 182,000 million respectively followed far away by Japan with an expenditure of US$ 65,400 million.

In Europe, see Figure 3, IDC predicts investment over US$ 241,000 million in 2022, with Occidental Europe holding the biggest share of the expense.

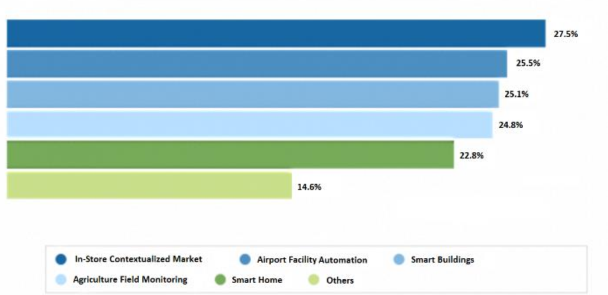

Figure 3: IoT use cases that are expected to deliver the fastest spending growth over the 2017-2022 forecast period in Europe (IDC, 2018a)

Heading Occidental Europe, Germany will invest US$ 35,000 million, followed by France and UK both with US$ 25,000 million spent along 2019.

We notice that at European level the distribution of the investment by industry is different from worldwide.

Biggest expense foreseen in 2019 would be in the manufacturing industry (US$ 20,000 million) followed by public services (US$ 19,000 million), retail (US$ 16,000 million) and finally transport (US$ 15,000 million), but worldwide, we find the biggest investment in the airport facilities' automation.

Nevertheless, the spent in IoT is led by consumers, which will exceed US$ 32,000 million in 2019 in home automation, personal wellbeing and connected vehicles. Concerning hardware, we are speaking of an amount of US$ 66,000 million, mainly spent in modules and sensors. With these figures, we may notice IoT significance and the evolution that this technology will have during the next years.

Another hint to remark is that this technology is progressing homogeneously in the sense that both Industry and users are adopting and embracing the goodness of it. This is fundamental, as new working generations will have incorporated these technologies and this will ease greatly the use of them at the industrial environment.

We all see that our Youngers naturally live with the latest technologies, while for older generations take more time to adapt to them or they simply reject them; this is part of human nature and must be considered. This also happened when other technologies such as computers and internet begun their existence and altered our lives.

2.2 WIRELESS COMMUNICATIONS IN INDUSTRY. 4.0 & 5G

It can be affirmed that the combination of the wireless evolution with new 5G network and so of Industry 4.0 will mean a turning point as 5G technology will solve problems that haven't been able to solve properly up to now and have meant an obstacle for the evolution of the future factories. 5G promises to be the answer in terms of flexibility and versatility that Industry 4.0 demands. But, what will be the advantages that 5G technology will give?.

- Enhanced mobile broadband speed and more capacity: up to 100x faster than 4G.
- Ultra-reliability and latency: could be less than a millisecond.
- Massive machine-type communications: can support a very high density of devices.
- An architecture more open to third parties via APIs.
- Network slicing: This concept that consists in a partition of the same physical network into multiple virtual networks, each one optimized for different applications, could save costs and have a faster time to market.

In the Table 1, a comparison with 4G technology and also with Wi-Fi 6, that is the proposed technology for industrial environments, can be seen:

WiFi 6 allows:
- To work with high density of devices connected, up to now a bottleneck for IoT.
- To reduce the interferences that makes that the efficiency of the data flows decrease.
- Incorporation of technology Target Wake Time (TWT) that admits more autonomy of the connected devices.
- Unless WiFi 5 or 8002.11 ac, the new standard can operate in the 2.4 GHz or 5 GHz frequency, this being very important as we could see later on.

When speaking of experience acquired in e-Flow project and key factors that can determine its deployment, the characteristics of the materials were appointed as one of them. At the moment of creating wireless infrastructures, 5G network works with frequencies ranging between 24 and 86 GHz, over 6 GHz of 4G network and future generations will be also working with range 30–300 GHz. Having this frequency range into account and that as much higher frequency, radio waves are more sensible to obstacles and also its materials, and being the worse metallic materials, that are plentiful in industrial environments but specially in shipyards and ships, technology 5G will find important difficulties in these types of environments.

WiFi 6 works with lower frequencies, even in 2.4 GHz is the solution found for industrial areas, but even so, in e-Flow project this frequency was used and the problems in environments with great metallic materials presence was important. That is why the promise of 5G in IoT world must be taken cautiously because its deployment success is largely conditioned by the surrounding.

Among 5G qualities is its low latency, an important characteristic for instance for remote vehicle control, as these types of operations require a quick answer and in ideal conditions the latency speed is under millisecond, esteeming that this technology can be 60-120 times faster than average latency of 4G. WiFi 6 doesn't reach this latency, and depending on the case, it might happen that ten milliseconds are not enough.

Low latency is a key factor for IoT focused to Industry 4.0 as if we add large download speed offered by 5G, twenty times faster than 4G, actual needs will be covered and those that may arise from now to short term (WiFi 6 allows larger download speed than 4G but only five times faster as much).

The demand for data traffic for devices that uses these types of networks is overcoming the forecasts and in this moment is growing by 40% to 70% annually (IoT Analytics).

Table 1. Comparison between 5G, 4G and WiFi 6 (International Telecommunications Union, 2018)

	5G	4G (LTE-A)	Wi-Fi 6
Enhanced mobile broadband speed: (peak data rate)	20 Gbps for downlink and 10 Gbps for uplink	1 Gbps for downlink and 500 Mbps for uplink	Approximately 4.8 Gbps
Massive machine type communication: (Number of connected devices per unit area)	1 million/km2	100 thousand devices/km^2	Not defined. Depends on the bandwidth required per device
Ultra-reliability and low latency:	Network latency is less than or equals to 1 millisecond with 99.999% assurance of delivery	Network latency is 10 milliseconds	Network latency is less than 10 milliseconds for 5Ghz band

In first half of 2019, see Figure 4 and Figure 5, the number of devices connected reached 17,000 million, of whose 7,000 million were IoT devices as IoT Analytics.

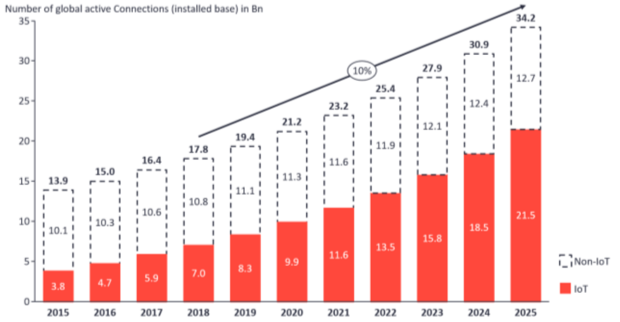

Figure 4: Evolution of active device connections worldwide (IoT Analytics)

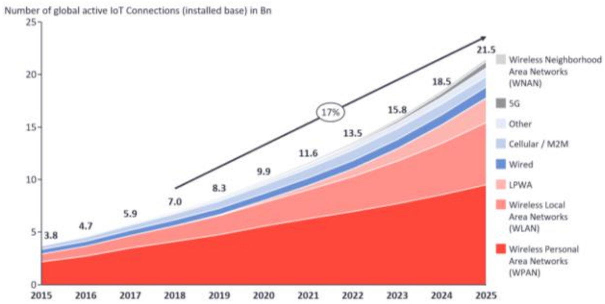

Figure 5: Evolution of the global number of Connected IoT Devices (IoT Analytics)

IoT applications are usually great data network consumers, as they compile Big Data amounts from a large devices variety and the perspective, as we have seen, is that the number of devices increases significantly so it is a key factor to have an efficient network capable of information collection, processing, transmission and analysis in real time.

If we focus in industrial environment, possible scenarios that we can find are mainly those shown in the charts below. Please notice that the Table 3 details the meaning of the numbering that appears in column High level requirements of Table 2.

Table 2: Scenarios of use and requisites for 5G applications related to Industry environment

USE CASE	APPLICATION	HIGH LEVEL REQUIREMENTS
Ultra-reliable communication	Industrial automation	[1],[2],[3],[4]
	Critical mission applications as e-health, hazardous environments, rescue missions etc..	[1],[2],[3],[4],[7]
	Vehicles without drivers	[2],[3],[4],[5],[6]
Communications type massive machines	Intelligent office	[1],[4],[7]
	Sensor networks (industrial, commercial, etc.)	[3],[4],[6],[7],[8]

It is expected that Virtual Reality (VR), Augmented Reality (AR) and Mixed Reality (MR) would also benefit thanks to 5G technology, as this is a strong data demander and up to now, although these devices allow wireless connection, speed and capacity of these network condition the evolution of these technologies in the wireless mode.

There is no doubt that 5G technology and future generations that will appear within 30 GHz to 300 GHz range will be the turning point and will be a key factor for environments 4.0 and subsequent.

There is no doubt that 5G technology and future generations that will appear within 30 GHz to 300 GHz range will be the turning point and will be a key factor for environments 4.0 and subsequent.

Table 3: 5G requisites of high level and spectrum implications

	HIGH LEVEL REQUIREMENTS	POTENTIAL IMPLICATIONS LINKED TO THE SPECTRUM
1	High reliability radio links	Impact of rain and other atmospheric effects on the availability of links at higher frequencies. For example, millimeter waves for outdoor operations.
2	High speed radio links	Wide carrier bandwidths. For example, 100 MHz of fronthaul / backhaul in gigabits
3	Low to ultra low latency form short to long range	Short range implies higher frequencies and Long range implies frequencies below 3GHz, for example.
4	Operation in congested environments	• Environment dominated by diffraction at lower frequencies. • Environment dominated by reflection at higher frequencies.
5	Ultra high reliability radio communications	Severe impact of rain and other atmospheric effects on the availability of links at higher frequencies, such as millimeter waves for outdoor operations
6	Operation near fast moving obstacles	Fading (variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency)
7	Penetration through floors / obstacles	Lower frequencies. For example, sub-1 GHz
8	Mesh networks	High speed distributed wireless backhaul (In a hierarchical telecommunications network the backhaul portion of the network comprises the intermediate links between the core network, or backbone network, and the small subnetworks at the edge of the network) operating in or out of band

2.3 VISION FROM AN USE CASE

At end of year 2011 E-Flow, integral system for evacuation project was launched; this Project was based in Ernö Péter Cosma's doctoral Thesis, co-author of this paper (Péter, 2014/a/b).

This Research & Development & Innovation (R&D&I) Project was developed within a consortium of technological companies and the Universidad Politécnica de Madrid, with the participation of two research teams of the Escuela Superior de Telecomunicaciones. This project, managed by Ernö Péter, is maybe one of the first tries of approaching the concept that now we call Digital Twin and from the e-Flow experience acquired along three years of development, important conclusions outcome, many of them directly related to the IoT and also duality between virtual model and reality, core concepts of Industry 4.0.

E-Flow aim was to lead an intelligent evacuation of complex infrastructures. The Thesis original idea was to act within a vessel, but later on the development was chosen to be done upon terrestrial infrastructures with a pilot project within the own Telecommunications Engineering School building as well as into a hospital facility (Fundación Instituto San José, Madrid).

Project goal was to create a physical infrastructure of services supported on devices that allowed data collecting by means of sensors of all kinds (moisture, smoke, occupation…) and also the possibility of interacting with the surroundings by means of a dynamic signalling system remotely controlled thanks to algorithms that optimize the signalization. Those algorithms, also created by the author of the Thesis, works under the real infrastructure conditions and at real time.

Besides this, a 3D model of the monitored area was created and provided with so named physical infrastructure. This model was used for simulation of evacuation processes of different areas through a simulation software also developed as part of the Thesis.

This Project held main blocks and technologies that revolve around Digital Twin: simulation, 3D model, IoT and among these, ubiquitous access to the information and the infrastructure control by means of any type of device with internet access.

The different main blocks are:

- Mobile scenario: Built of technological components developed to allow access to the information and the advanced mobile communications. These technologies are focused to ubiquitous access to the information generated by the sensors.
- Fixed scenario: This block includes all developments that belongs to network infrastructures and services created for supporting the fixed scenario as well as the sensors system.
- Sensorization scenario: Necessary hardware and/or software developments to obtain data from the environment and interaction with actuators. Wireless technology was used for allowing quick start and ease of installation, as well as fast interaction.
- External means: Emergency means would have access to all the information in real time from the sensors and from interactions happened in the mobile scenario; thus, emergency means can plan actions from accurate knowledge of the real situation.

The entire monitoring infrastructure was supported by two elements developed in the project:

MOTAS (Wireless nodes) are small devices linking sensors/actuators that need less processing and power consumption.

These devices comply with key requisites as:

- Easy installation.
- Power feeding can be made by several means to guarantee the operation under any circumstance:
  - Own battery with large autonomy (depending on the energetic demand of the sensors it could be several months).
  - Connection to electricity grid.
  - Possibility of solar panel installation.
- Reliable and robust communication among devices: communication is a key factor to guarantee an optimal infrastructure so the loss of one Mota won't be significant for its impact in the communication. It is important to remark that, to the objective to be used as fundamental part of the infrastructure to support dynamic evacuation system, the failure of one of these Motas implied the loss of the area that was being monitored for, so this area would cease to be considered as valid to belong to a possible evacuation route.
- To incorporate an application in low-level language that allows the managing of the information coming from the sensors. This software could also add information filtering possibilities, timing and alert warnings if sensors have values out of range etc.
- Base plate incorporated different sensor types but it is also provided with additionally ports for other sensors and actuators that would be necessary.

Each Mota set was provided of a central Mota that is the one that connects with the concentrator, device that collects information provided for all system Motas. In the Figure 6, an example of the Mota prototype developed during the e-Flow project.

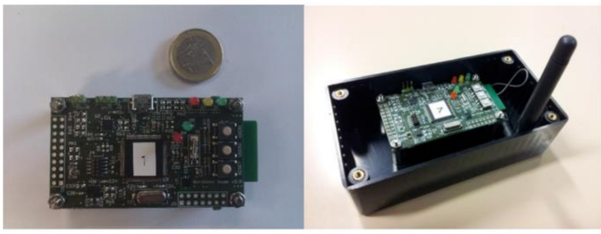

Figure 6: Mota prototype developed in e-Flow project

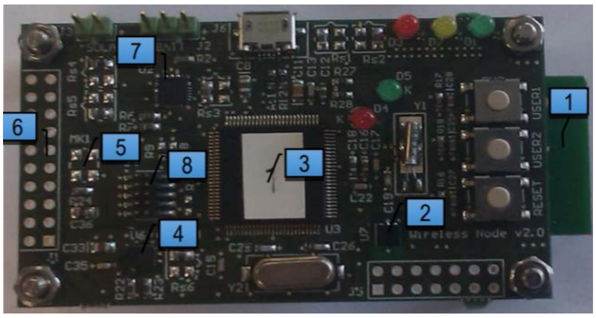

Figure 7: Image with the most important components of the Mota

Where the numbers in the Figure 7 means:

1. Radio Frequency (RF) module.
2. Moisture and temperature sensor.
3. PSoC.
4. Accelerometer.
5. Microphone.
6. Expansion port.
7. Power supply manager.
8. Debugging interface Joint Test Action Group (JTAG).

All Motas used were based in Programmable System on Chip (PSoC) technology.

Data concentrator. It is a computer power enough to manage Motas information and it is capable of manage sensors more demanding concerning data.

This concentrator was based in a Texas Instruments processor OMAP-L137 and allows to execute complex applications and managing of big information volumes.

In this project, two fundamental devices were also developed, that basically were dedicated Motas:

- Dynamic signalling device: This Mota is an actuator device receiving remote orders to perform several programmed actions, in this case to configure a thirty leds matrix to appoint the direction people should follow. That direction was determined depending on what the evacuation coordinator had decided from the application managed through his tablet based in the information of the sensors that shows the infrastructure situation and also based in the algorithm developed to propose the best evacuation route. This device had eight different configurations. An acoustic alarm was also added and a presence detector to minimize power consumption in case of electrical grid breakdown and the use of the power from a battery was needed, so leds remain off while nobody is around, this operation is only feasible for certain cases.
- Device for access control to determine capacity: In terms of evacuation, a key factor is to determine quantity of persons, for doing so there are a lot of different technologies and all of them with its advantages and disadvantages. The knowledge of people's location is key, and it also is included in the concept of Digital Twin in Shipyard 4.0. Technologies employed to give an answer to this need are: Infrared technology, Global Positioning System (GPS), Assisted Global Positioning Systems, Bluetooth, use of tags Wi-Fi, Ultra-Wide Band (UWB), Ultrasounds, RFID active and passive, ZigBee, fixed cameras, fixed cameras, Kinect technology, scanner laser 3D, Indoor Positioning System (IPS), presence sensors. In the e-Flow project, a technology based in the infrared scanner with a resolution of 64 pixels and a frequency of scanning of ten images/second was chosen. This device analyses the sequence of images by means of an algorithm of shapes recognition that detects in plan-view the humanoid silhouettes and it is capable to determine the sense of movement so, if a sensor is positioned over an access the entrance or exiting of the persons to /from a room can be determined. If the sensor is placed at three meters height, it is capable to cover an area of 3x3 m^2.The problem with this type of sensor is the calibration depending on the floor temperature and the height of the persons.

E-Flow was a project that gave an answer to a situation stuck in the past, based on rigid rules and not from the point of view of the incident and considering it as a live and changing process to what the resources must adapt to.

Reliability, strength and accessibility or ubiquity of the information were the three bases upon this project was supported, and its possibilities got beyond dynamic managing of the evacuation as the infrastructure displayed could also be used for many other purposes and functionalities derived from the area monitoring and the fact that it is supported on a data network.

Modularity of the different elements implied allowed the system scalability and the possibility of using the infrastructure for other developments, from new interaction ways with individuals to the chance of anticipate to hazardous or unwanted situations.

This Project wasn't in the path of what we now call Industry 4.0 as this concept wasn't even used, but it anticipated and approached the main problems that had to be considered to display these types of infrastructures.

It could be determined that the key factor that could make that a system with these features could or not succeed while implemented, depended on a few factors, if we consider aspects related to infrastructure only:

Communication's infrastructure: restrictions due to the own infrastructure availability, due to technological limitations that sometimes were difficult to overcome. In the case of e-Flow, as this was a system aimed for its potential for emergency situations, this communication had to be granted; for doing so, it was considered to incorporate communications Peer to Peer (P2P), WiFi, Bluetooth and 3G or 4G, so if any of these systems collapsed, another communication channel could be used. Communication among Motas and of the Mota to the concentrator was performed by means of a RF module connected to an antenna dipole type tuned to 2.4GHz, suitable frequency to increase the gain and enlarge the range.

Materials: Another critical aspect of the displays were the building materials used in the infrastructure where the display was made. Radio frequency transmission through infrastructures that used materials that blocked a good emission/reception of wireless signals is a very restricting factor and condition this type of deployment.

Mains: In such an infrastructure, to guarantee the supply of energy to all devices that it is made of is a decisive factor. As it was already seen in e-Flow, special care was taken when devices were thought to work under any circumstance, supplying them with batteries and even the possibility of installing solar panels.

Reliability and heavy-duty: These two points derive directly form the above three ones. To provide the elements that makes up the infrastructure with the possibility of auto-diagnosis and auto-calibration to detect problems by themselves, or to be able to receive orders so these checks can be made remotely are functionalities that allow the confidence to the system.

Redundancy: To grant the access to the information so if a server that stores and manage data collected fails, this doesn't imply that the system won't work. In e-Flow project, all the information provided by sensors and all communications among the own means of the infrastructure in danger and with all emergency means through web app designed especially for tablets and mobiles, was recorded in remote redundant servers, to grant information availability and for future uses.

Quickness: Depending on the information importance, the need to access to the situation at real time with minimum delay can mean a big difference depending on the application.

Quantity of data (storage capacity): Communication of the data coming from the sensors in timer mode, can mean a big amount of data, which implies an increasing capacity need, when not all the information is necessary. Thus, the objective was that the Motas could pre-filter the information and send the representative information only; moreover, this information could be directed to the concentrators that could also treat locally the information.

Usability (user interface): A key factor was also to have a clear view of the user that would handle the data and the way that would interact with the infrastructure. E-Flow project was considered as a service infrastructure that may be used for different profile types:

- Emergency coordinator profile: they would have access to all infrastructure and its sensors in real time and also to the dynamic signals system management that was supported by the algorithm managing that signalization. This coordinator would access through a device such as a tablet to all possibilities. Besides these functionalities, the coordinator would access to a WhatsApp-type functionality that would allow them to communicate with the rest of the team.
- Emergency staff: These users would access by means of a smartphone type device and would only have enabled the WhatsApp-type function.
- External emergency means: Interface could be the same one the coordinator has, and also enable same privileges, use from PC or tablet.
- Other users: The deployment for this infrastructure that luckily is not going to ever being used can be of value to be used for other purposes beyond evacuation and that may vary depending on the infrastructure they are installing the system: maintenance, services, booking management, etc.… imagination is the limit.

Concerning interface it was clear that the use of smartphones wasn't the best way to interact for the persons that may take active part in an evacuation, not for a coordinator profile that may follow remotely all the event. The usage of a device that needed to be operative manually is a handicap and this is true for an emergency environment and for an operator that is working with a machine, welding or installing equipment. In this case, the device ought to be hands-free. Google glass and HoloLens, for instance, offer this possibility; nevertheless, HoloLens was rejected as the device was very cumbersome, so the ideal one to use would be Google glass or similar, the smaller the better. Size was not the single factor to consider, the device had to have also autonomous enough for a complete working journey, light and ergonomic, also allowing interaction based in voice commanding and here we must count with the natural language recognition with a camera that can shoot and even send video signal in real time.

Scalability: This type of infrastructure has to have great flexibility while incorporating new devices, sensors, actuators. For doing so, a key factor was the standardization of all these elements.

IoT means cooperation among machines, evaluation of sensor data for a more efficient control. In e-Flow it was soon detected that the lack of a standard, a common language for all systems communication was a handicap that led to create a specific infrastructure for the e-flow project and once the decision was taken, the whole infrastructure would be conditioned for this, greatly limiting the scalability of the project, due to the data structure, actuators, motors, … may vary from one manufacturer to another. This does not mean that the integration of new devices was not possible, but the adaptation process would be more complex to suit to each case, so we get an integrated solution, which means great effort for developers. This lack of standardization is one of the reasons that IoT is still in an emerging state.

Five years ago, World Wide Web Consortium (W3C), an international organism with relevance concerning internet standards, begun to play a key role, as the standardization was a fundamental need. This organism has agreed a basic standard aiming to facilitate cooperation between devices. Thanks to this, each object becomes a digital data block that is characterized by these elements:

- Properties: switch on/off, etc.
- Information about accidents and events: battery level, etc.
- Relevant Meta Data: Object location, etc.

There is still a long way in terms of standardization but all actor are aware of the importance of it and how its definition would mean for IoT future.

Security: IoT offers a gateway to an enormous infrastructure data, of equipment, of people… All of this is sensible information that must be protected, but through IoT devices we can access to information beyond the intended use, what it is pretended to be controlled or monitored. It is because into account that this type of systems may be connected to other services, systems or infrastructures that may be accessible as well from the multitude of new accesses that IoT offers and be the gateway to steal or destroy critical information for a company, person or institution, control a device remotely.

We all have heard about security fails for certain connected vehicles, how hackers have been capable to control a vehicle remotely while driver and passengers are inside. This means that security is a key factor.

Many security experts alerts that IoT devices' security are far behind hacker's capacity to break companies' infrastructures; this is that IoT are security breaches vulnerable to hacker's attack and it is necessary a great effort to avoid this.

Sensors, controllers and many other devices that may be connected to the network does not have a protection better than an user ID and a key factory installed and in many cases, both the user and the key, easy to guess, aren't normally modified while implementing, but although they would be modified, there are no warnings set, so these are open gates for attackers. Ponemon Institute and Aruba, a Hewlett Packard Enterprise Company interviewed 3,800 security professionals and the results were that 77% of these experts consider that IoT devices performing monitoring and minor tasks mean a potential danger in terms of security. Only 24% of the professionals interviewed believed that their organization's IoT devices were secured.

These arguments were the same ones that were heard concerning Cloud and the security breach that it could be for companies, users and services more or less critical. A time pass by, confidence in this service has increased, due to the work that the companies that provide Cloud services are carrying out concerning security, as they are aware that Cloud security and granting it is basic when offering Cloud services. Concerning Industry 4.0, Cloud issue is a must and so Industry 4.0 goes along with Cloud. IoT as well requires this confidence stage that Cloud has reached, and it has to be driven towards that direction, but IoT is just another acronym in Industry 4.0 and it is not optative, IoT is part of the concept base. As already said when speaking about the e-Flow project experience, IoT depends directly of the communications infrastructures so it is important to speak about an important issue that is fundamental for Industry 4.0 and also is relevant for IoT future, and this is the new 5G network.

3. BIG DATA AND ANALYTICS. MORE THAN DATA

There is a huge volume of information available for a correct design and building of vessels and shipyards. It is important to expose that the context where all this information is, from one perspective, really complex given the number of regulations, guidelines and, at the end, rules that can apply when designing a vessel or a shipyard. However, seen from a different perspective, it becomes a huge opportunity to exploit all this information in a much more intelligent manner. The aim of this document is providing a better understanding of what it means by intelligent manner.

There are a number of concepts that coexist and very often lead to certain level of confusion: data, Big Data, Analytics, Data Analytics, Predictive Analytics, Prescriptive Analytics… all in all they're embedded into a wider concept of Cognitive.

Besides, it must be conscious of the fact that information is not yet limited by the list of information depicted in the previous paragraph. What it is declared in that piece is limited to what is called Structured Data. However, numerous studies point to the fact that this structured data cover only a 20% of the information available for us to use.

It is also a reality that there's a huge and continuous generation of information that does not reside in such structured sources of information: manuals, guidelines, reports … contain huge volumes of information that is actually embedded in pieces of information that it is commonly called documents. All those sources of information currently provide an enormous source of data that can be extracted for those encapsulating binders that it is known as documents.

On the other hand, relatively recent evolution in Computing Capacity, formerly named High Capacity Computing, around 2011-2012 brought a key new capabilities that, jointly with pure data management, have carried us to a much powerful capacity to manage that information, as shown in Figure 8.

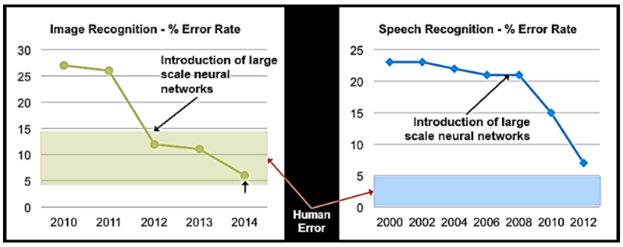

Figure 8: Evolution in Computing Capacity (Muñoz and Pérez, 2017)

By bringing all together is where it is foreseen a huge growth for the information o coming up that can directly be applied to vessel and shipyard construction, this is what it could called Cognitive Naval Construction by using Cognitive Capabilities.

Let's talk about how all these Cognitive Capabilities work together with a common purpose, as explained above, to improve the design and construction of offshore elements.

The image below, Figure 9, compiles the set of elements within the concept of Cognitive Systems that can be simply applied to Cognitive Naval Systems, given, as described above, the complexity of information (data, rules, guidelines …) that must be managed to improve the design and constructions of vessels and shipyards.

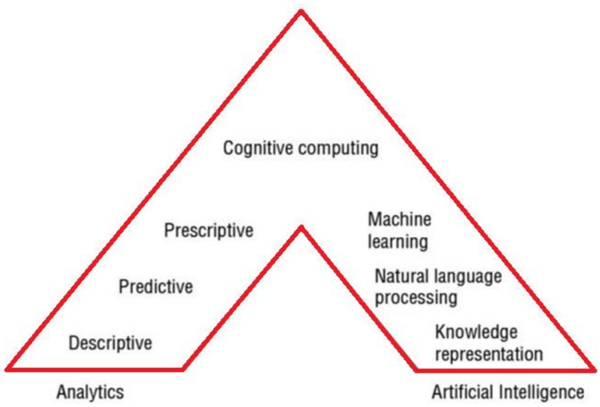

Figure 9: Cognitive Systems Components (Hurwitz et al., 2015)

Vessel manufacturers and vessel operators have been storing high volumes of data for years. This volume of information will dramatically increase in the future by connecting every single component in the vessel or shipyard to a data lake where all this information can be analysed and exploited. This analysis can be done from different perspectives and also with differed purposes:

- Descriptive: technology has currently evolved so that it can very easily gather and store data by connecting to a cloud system in almost, increasingly closer, to real time. By collecting all this stored data either when constructing or operating the vessel, can already provide an immediate and real-time information of the vessel operation and behaviour so that I can use that information to identify early alerts based on this immediate information gathering. By providing all this analytical capabilities in place vessel operators can get a much higher understating of the vessel behaviour much beyond human reaction capacity and besides, this can be immediately compared with historical information so that abnormal behaviour can also be identified and notified properly.
- Predictive: as seen before gathering and analysis of information of the operation and construction can provide immediate happening information, however, modern analytical capabilities allow us to define behavioural patterns based in historical data. By doing it, it´s likely to define statistical patterns that will not only define regular behaviour but also data trends on existing set of data. By using those data trends it is possible to predict what the outcoming data will be in a certain period of time with a define level of certainty. By working this way it could be simply predicted whether, based on the data that is being collected, the behaviour of a particular component in the vessel will most likely deviate from a regular behaviour thus alerting, and hence allowing to avoid, any undesired behaviour in vessel components and operations.
- Prescriptive: once it has been seen that it could be monitored both construction and operational data in real time and also predict the behaviour of any particular component that is measured in the vessel, it may wonder whether it could be taken the most appropriate actions in advance upon a particular undesired behaviour of a component. The answer is obviously yes; by performing the appropriate data analysis it could be also suggested what the most suitable actions will be and also when these actions should be done in order to minimize impact of those actions to be done.

By combining this three analytical capabilities it is feasible to find different areas for improvement like: predictive quality, predictive maintenance, prescriptive maintenance, and so on. Later on in this technical paper, it will be exposed the meeting of placing this prescriptive capability at the top of the angle of the diagram shown in Figure 9, thus highlighting the close connection with the Cognitive branch in that diagram.

4. ARTIFICIAL INTELLIGENCE

Control system in the ship can include some AI predictive processes integrated in the bridge overall control system, which helps to deduce the consequences of maintenance operations, from doing in the correct time as well as delaying or skipping them (Pérez et al., 2018).

This procedure applied is including in the edge/fog computing methods, due to only involves the ship inner communication network, delaying the massive download of operation data upon arrival at port. During navigation data transfer should be only applied to critical operations.

Navigation data can be also useful in design and production phases, to correct some processes in order to obtain more efficient systems, and more efficient designs. This is only possible applying some AI process to this data, classifying, processing and getting some results.

This working methodology, to be deeply profitable for both actors, requires a joint venture between ship-owner and shipbuilder.

AI processes based on navigation data, in the multi-boat paradigm, can obtain information to improve design and production processes, which can be applied to the current series, or an evolved variant of this vessel type, or other ones (Benayas-Ayuso and Pérez, 2019).

Ship operation phase is not the only one which produces a set of Big Data to be processed by an AI System, in the production phase, some calculus can be done in the workshops or even delegated in a cloud system, to be distributed.

This data, in CAD AI tools, can be classified generating working sequences, design automatic checks, and automatic design processes.

Now, setting the focus on the Designer, sometimes for the tight schedule or for the start-stop working requirements of the design office, like meetings, designer does not have much time for its principal task: create full effective designs, which requires concentration and calm.

This problem can be solved by AI, applying some design rules, and exposing a bunch of effective solutions, delegating the final decision on designer but helping discarding a big group of previous solutions which have shown some problems, i.e. lessons learned.

At this point, some sceptic people can think: AI is going to substitute designers work, but AI is going to augment the capabilities of this designer, making work less stressing and more efficient.

All available AI processes which can be applied in a CAD System to help designer are represented in Figure 10.

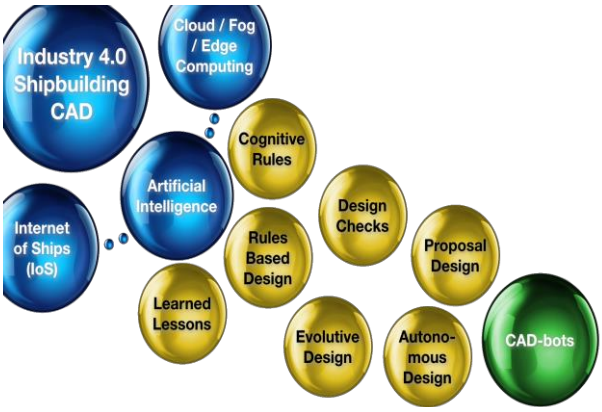

Figure 10: AI Evolution in the Shipbuilding CAD World (Benayas-Ayuso and Pérez, 2019)

4.1 FIRST STAGE

AI applied to a CAD System should be based on the standard ways to control a design:

- Rules based design.
- Lessons learned.
- Cognitive rules.

First on the list, rules based design, it is the shipyard standards book of rules. These rules are the base of any shipyard design, and are the first one to be learned by our AI System. To improve it, some other technologies can be applied, like Cognitive AI, which is the base of natural language processing in an AI solution. This cognitive AI can be run over the shipyard standards book of rules, and with some user help, try to improve understanding in application of the rules from the AI tool. All AI solution requires a specific time to learn the correct ways to apply the set of rules.

Next step, also based on natural language spelling, can be add the lessons learned to our AI solution, creating a mixed ecosystem of rules to be applied to the current design process. And last step, but not less important, Cognitive Rules, these rules are deduced from the current design and also from production error input in the CAD System, like design incidences.

4.2 SECOND STAGE

With all first levels fulfil, second level steps can be applied:

- Design checks.
- Evolutive design.

First improvement applied in the CAD AI is the capability, in a non-highly intrusive manner, help user with the design, offering a list of design rule application failure to the current work (Benayas-Ayuso and Pérez, 2019).

This list, if is based on the second part of this tools, evolutive design, can not only the design issues, also offer an improved solution to user. The bunch of solutions offered is based on the experience accumulated to similar issues found in the historic of the design improvements applied. These steps generate lessons learned input in the AI System. Second level tools requires a high level design knowledge to be trained faster, like a design checker, supervisor or discipline manager role.

4.3 THIRD STAGE

Once the previous two stages have been accomplish their training, a third level of tools arise:

- Proposal design.
- Autonomous design.

The first of this stage tool, proposal design, is one of the most required tool, in a natural language interchange: Please, which are the best ways to connect this fittings with the main equipment?.

Based on the cognitive learning process of the CAD AI tools, the answer can be interpreted in machine language as route some pipe lines which connects both items and let us select the better one on my design criteria or provide the best alternative between several existing ones. This last step also generate lessons learned input in the AI.

The second of this third level tool, autonomous design, require a huge collection of approvals of the previous question, and based on them and in the Piping & Instrumentation (P&I) diagrams, can look for the best location for fittings in the ship, as well as, create a piping solution for that system. This step generate Cognitive Rules input in the AI System.

These third level tools require months or years of training in the CAD AI tools, creating which can be named as CAD-bots, autonomous designers which, based on a simple input, P&I diagrams, can recreate a 3D accurate design, which accomplices which the most when not all design rules applied.

4.4 CAD-BOTS

These CAD-bots are AI augmented cognitive bots which can perform automatically some design parts based on the lessons learned and cognitive rules, but always fulfilling the complete list of the shipyard standards book of rules.

There is one exception, in the case of contradictory ones. At this point, AI tools, represented by the CAD-bots can offer designer which rules have a conflict and reapply approved rule to the previous design with reduced effort.

These CAD-bots could design and propose to the user a bunch of the most effective solutions, helping in several difficult design activities, like the management of the impact of deep design changes, or even ship-owner or classification rule changes, augmenting user capabilities.

CAD-bots are not going to resolve all design issues, but their instructions lead to achieve and accomplish the most tedious tasks as well as help in some design modifications.

5. SIMULATION: A REAL ALTERNATIVE TO REALITY

During the engineering phase, simulation tools and model tests are intensively used:

- To analyse structure, i.e. finite elements.
- To analyse hydrodynamics, as CFD´s or tests in the model basin.
- To design and improve production processes.
- Etc.

Simulation also has its reason for being in the world of plant operations.

As will be seen in the section dedicated to Digital Twin, simulation can be an important ally in a shipyard, contributing decisively in the optimization of resources, both at the level of human resources and infrastructure as well as the rapid adaptation to new projects.

It is important to emphasize the issues related to plant safety: simulation models will provide the necessary information to be able to decide which will be configuration of the facility that could provide the optimum results for both:

- Production: definition and optimization of workflows in physical spaces.
- Safety requirements: distribution of spaces to ensure a proper evacuation in case of emergency and the definition of the Evacuation Plan.

A Shipyard 4.0 that implements technologies such as the use of autonomous vehicles, requires a particularly detailed analysis of the spaces, workers interactions, assets location and autonomous vehicles' paths. For this purpose, simulation tools become fundamental to analyse and provide solutions for the difficulties that could be involved due to the coexistence of autonomous vehicles and workers into the same working space.

A key factor is the constant progress of developments in the world of videogames and the potential that it is demonstrating to have in the world of the engineering.

These game development platforms natively offer access to a virtual world that includes physics, materials, animation, etc. allowing the creation of photorealistic environments in which to have the Digital Twin of the product and the shipyard, as well as the workers and vehicles that interact in it. Once done, there is free way for simulation in this virtual environment.

With these tools, it will be possible to analyse the different distribution and operation's options into the virtual world and test them under different conditions, like for example:

- Workers and autonomous vehicles operating simultaneously with different routing alternatives.
- Different environmental conditions: light, humidity, temperature.
- Failure of some systems.
- Product assembly operations requiring the definition of operation strategies.
- Facilitate evacuation process under different conditions.
- Etc.

The creation of the connection between the 3D CAD Model of the product and the infrastructure in which the product is manufactured, and the game development platform, opens the door to endless possibilities, in addition to the simulation itself. In many cases, the core of the products that offers the implementation of Digital Twin and the access to VR and AR technologies is based on a Video Game development platform. In the paper "the use of CAD Systems to manage modularity in multi-role warships" (Pérez and Péter, 2019) it is detailed how CAD tools could help in the design of this kind of warships when we combine simulation and a concept that can be called variants.

If a CAD System includes the possibility to work with variants, the complex case of the design and construction of multi-role warships can be faced in better conditions.

In that case, the importance of the simulation of each variant before taking any decision is a key factor.

6. CLOUD, CYBERSECURITY AND BLOCKCHAIN

Cloud computing requires transfer of sensitive data through an external network to our system, where it is processed and the response, which can include even more delicate data, used in the client system.

Some crypto processes are required to hide this data to curious, or even malicious, people. These processes require a secured channel, a double check to validate the information and some special operations all developed in the cybersecurity paradigms.

Based on those paradigms, in 2009, the blockchain methods, designed in 1991, are applied to cryptocurrency opening a new interchange trusted world which ends with the bank intermediary requirement in monetary transactions (Nakamoto, 2009).

This cybersecurity paradigm opens a new tool for distributed and shared work in all the industries, even more in shipbuilding, and its huge security requirements sibling, naval shipbuilding.

Blockchain technology offers a secure channel which requires an invitation, special program which knows all connection data, and where every operation performed is validated for all available connections and saved in a non-modifiable way, and where all the agents have a full copy of these operations, generating a trusted work methodology.

A CAD tool that includes the possibility of a blockchain creation per each distributed work, and which locks items based on the assignation to a blockchain operation can be included in the new era of Industry 4.0.

7. VIRTUAL REALITY, AUGMENTED REALITY AND MIXED REALITY. A NEW WORLD FOR OUR SENSES.

7.1 AR AND VR TECHNOLOGIES

Both AR and VR are technologies that cannot be considered as new, especially VR, whose origins go back to the Second World War.

Until not long ago, the use of VR in industrial area was something very rare, due to among other, to the high cost of this technology, but up to now and thanks to the recent progress in computer sciences, miniaturization, storage, graphic processing and the new high-resolution screens as well as technology is cheaper, VR and AR have revived.

Today, and thanks to the possibility of using smartphone for watching/interact in VR environments or visualize AR contents, these technologies are available to everyone (vr.google.com/cardboard), without need of having a very powerful device.

Another sector that drives these types of technologies are the video games world, creating increasingly real environments in which the users can feel really immersed thanks to VR glasses and the tracking system allow a deeper immersion allowing to transfer the own individual movements, action in real environment linked to the action in real world.

Technologies as the developed in the Leap Motion (leapmotion.com), in which on time scanning of the user's hands can be made, creating a duplicate in VR copying fingers' movement, evolve at high speed to make the experience to be more immersive.

Besides VR and AR, also exist Mixed Reality, Hybrid Reality or Merged Reality. This concept is newer than the preceding's and which potential is out of question, consists in in the combination of the physical world and virtual world in a way that all of them coexist. This assumes that in these types of environments can happen a complete interaction between reality and virtual environment.

Nevertheless, AR is the technology that may seem to have more power in industrial sectors, proving in the cases it has been implemented that:

- Significant error reduction.
- Increase in productivity.
- Drop in employee injuries.
- Reduction of ergonomics issues.
- Favour collaborative environment.
- Improves efficiency.

The use of these technologies is more present and every day more important in automotive technology and also aerospace industry. In other industries, the progress is slower, as for instance in the shipbuilding, but for Digital Twin, VR and AR comes along and Digital Twin is an unstoppable wave in Industry 4.0 and Shipyard 4.0.

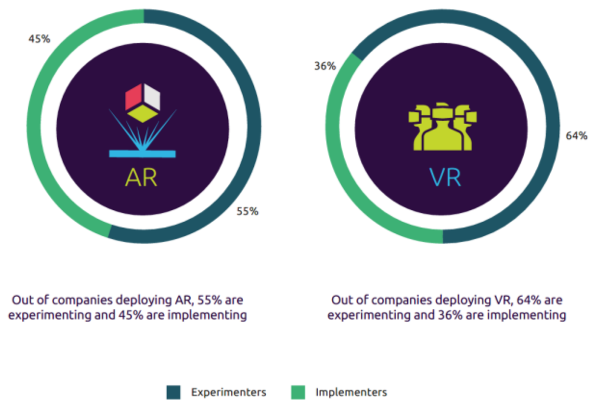

Figure 11: Out of companies deploying AR/VR, implementation levels by organization category (Capgemini Research Institute, 2018b)

In Figure 11, we may appreciate as principal implementations of the companies are AR, while at experimentation VR overpasses AR and in Figure 12, it can be seen the implementation level of both technologies country by country.

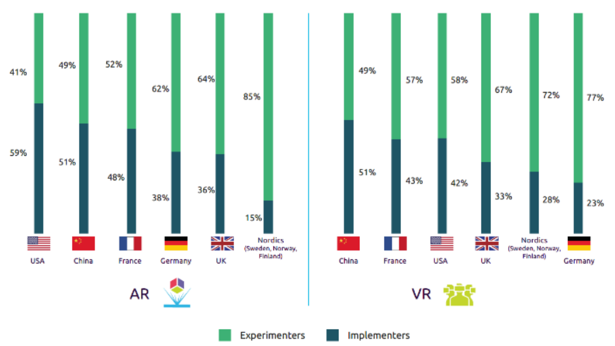

Figure 12: Out of companies deploying AR/VR, implementation levels by country (Capgemini Research Institute, 2018b)

A fundamental facet of both technologies and that conditions completely its use, is the device that will allow to access to AR or VR.

AR consists in the superposition of digital elements over physical world; this way, digital elements add new details to real world thus creating an augmented experience of the reality. The devices with which this superposition can be reached can be divided into two groups depending on their limitations that their use means for the development of other activities simultaneously to visualization:

- Restrictive: Smartphones and tablets.
- Not restrictive: Smart Glasses and other types of head-mounted devices.

The first ones are quite affordable devices, available to all types of users but they have the important disadvantage that the user who accesses the AR with this type of device will not be able to execute tasks with their hands at the same time, as at least one of them must be used for holding the device.

These types of devices do not exploit the potential of AR completely, although it is true that for those uses that require complex operations needing user interfaces that combine different operations in which AR is only a small part of the features that provides, this type of device is the best option, especially tablets.

Smartphones have an excessively small screen, and, except for the portability, it does not provide a greater advantage compared to a tablet.

The true potential of AR can be obtained with Smart Glasses devices, that allow to combine AR and true reality, without interaction with our hands, although that is not entirely true as these devices normally have touch pads and/or buttons to access to functionalities and interact with overlapping contents to reality.

The combination of this type of devices and the technologies of gestural recognition and natural language interpretation is what will allow to exploit the AR in its maximum expression since in this way the immersion is total and the interference of these devices in other types of actions that can be made by the operator is minimal or non-existent.

The devices that are closest to this line are Google Glass (google.com/glass/start) for industrial use, Hololens (microsoft.com/en-us/hololens/hardware) and Magic Leap (magicleap.com).

Google Glass is, due to its dimensions and lightness, a device that is nearer the ideal while working on site. Hololens & Magic Leap that can also work with mixed reality, are heavier devices and less ergonomic when working with them, and also not suitable to work when ruggedized equipment is needed or there is a hazardous environment for sensible devices, as can be a shipyard.

Hololens and Magic Leap are more suitable for office environment or exceptional use during construction outside.

However, VR creates its own pure digital surround in which the user is immersed, providing a sensorial experience that can be at several levels:

- Visual: Complete visualization and integration of the user within virtual environment, with visualization capacity in any direction.
  This integration can be in a:
  - Camera-way only, moving around virtual scenario, being the camera's movement the conductor, controlled or not by the own user.
  - Or through a digital avatar so the user can see through the avatar's eyes and it experiences the interactions of the avatar itself with the scenario, under the effect of the obstacles of the environment or the possibilities of interaction with virtual objects.
- Hearing: These virtual environments use the audio for augmenting the immersion experience, playing with sounds from the different elements existing in the virtual scenario with environments generally very well-achieved scenarios in which sounds are very reliable about position of them in the location.
- Tactile: There are many devices developed and that are being developed so the tactile experience is really immersive, and the user is able to perceive what he touches with his virtual hands or even with the rest of the body with integral suits. This way, user is physically conscient of the reality, something that only exists virtually, and can interact with the object in a completely natural way: perception of hardness, texture, etc.
- Olfactory: A field also under work.

Another important factor for VR is how we interact with it. We already saw that tactile experience is a way to interact with these environments, but this interaction is also possible without so deep immersion level but offering easiness enough in handling for a person for doing it efficiently. The simplest way is by means of a typical cursors system to go forward and backwards, as well as by menus that can show up if we observe an object and can push a button or even if the system determines that the time that you observe an object is enough to display a menu linked to that object or information of it.

In a second level, we could place the devices that a user can hold with his hands, as controllers and see those devices in the virtual world so the interaction with the surround is through them. We can realize this technology in famous Oculus rift (Holz, 2013) and HTC vive (vive.com).

In a third level we could place Leap Motion (leapmotion.com), a device that scans user's hands and is capable of identify each finger in real time, making a 3D plot of the hands in the virtual scenario and being this representation what interacts with the environment. Most advanced and immersive devices are gloves and even full suits.

Another essential interaction level is the own user's movement within scenario. Tracing systems are the most interesting as they allow to position in space, determine to what height you are, i.e. bended or standing still, and to approach to virtual objects normally to see details.

7.2 AR AND VR APPLICATIONS

AR application in Industry could be wide, and in part also offers many of the possibilities that VR proposes but it is necessary to distinguish in each case what is the best option.

It has been proved that AR is really good at:

- Give instructions of a determined process to an operator while working with an equipment.
- Being able to preview a disassembly process step by step for a concrete equipment that is existent and that is the one the operator will work with, so he can execute each step with aid of AR in that moment.
- Applications for remote assistance, to have available a system that allows to contact with an assistant in real time, with you being in front of the problem and that the camera of your AR device shows the assistance the problem you are facing in real time so that the assistant can recommend you next steps.

AR has a strong link with reality; this doesn't happen the same way with VR, but if this VR is used over Digital Twin, the link is stronger. This link with reality consists on the exploiting and visualization of the information generated by IoT. AR allows as well to overlap the information generated by the IoT infrastructure directly, see history, trends, forecasts, warnings…. Never-ending possibilities that Digital Twin, through VR could also offer remotely, being able in a future, who knows, to reach a completely remote management of a complex infrastructure interacting with Digital Twin.

Already said, repair and maintenance works along with design and assembly are the principal activities where these types of technologies can provide added value.

Concerning repair and maintenance works, main applications can be found in:

- Digital manuals visualization, videos etc. integrated into the virtual scenario in VR or overlapped to reality in AR.

- Remote assistance. Facing a problem that the user cannot solve, he can contact to an assistant that can see what he sees and recommend actions.
- Visualization of hidden elements by physical barriers overlapping 3D model of these hidden geometries versus reality where cannot be seen, and also interact with that virtual element to request information, move… thanks to AR.
- Allow to reproduce assembly/disassembly tasks or other types of operations, visualize explicative infographics on a machine's functionality etc.
- In design and assembly, watch digitally stored information of the design.
- Simulate the behaviour of a determined asset in conditions generated by a virtual scenario.
- Visualization of the models in different conditions, surrounds, applying different materials, colours etc. To analyse the aspect it could have in real conditions and take decisions.
- Overlap 3D model on the real model.
- Multiuser collaborative environments to take decision around a design/prototype so costs for creating one or several real prototypes are reduced.

Although AR requires of a more complex implementation within the productive protocols of a company, it has been proved that the results obtained are more profitable as the case is more complex.

VR has been the most widely used and along longest time especially in training environments, design checks, commercial, etc. It continues to be string in these areas, but now more homogeneously, as this technology is more affordable than several years ago, and also, the evolution of the implied technologies has made the experience to be more immersive and powerful.

The area of training is the one that foresees more application in combination with Gamification concept as tool to speed up and strengthen workers training.

This idea has special interest when operating with complex infrastructures that require high quality training for both working skills as working in safe and security conditions; Scenarios could be created where users could prove their knowledge, detecting as well critical points, leading to a redesign if the analysis of the generated data within the virtual scenario shows any problem.

Another important use of VR is the possibility of visualization of a prototype prior to manufacture. This possibility also exists with AR, but in this case it seems more interesting as we can position the prototype in different scenarios under different conditions or lightings, and if we add the chance of having a collaborative environment where several users can interact on the same prototype, not even being at the same place, the potential is enormous. This methodology has been proved greatly efficient where implemented, especially in automotive industry as it minimizes email exchange and meeting numbers to agree design features among all parties.

But being these technologies outstanding and with enormous potentials, it is decisive that it fits to a purpose in each case, as the implementation effort compensates and really add value.

In any case, it is not enough to will to implement these technologies, they must be supported on an infrastructure already technified in respect to equipment and also concerning people involved, as they have to be able to work and take the outmost of the advantages that these technologies represent.

When speaking of technological infrastructure necessary we mean:

- Availability of contents, being these contents: specifications, metrics, parameter values and sensor data, manuals, geometries, schemas, etc.
- Minimize risks of implementation supporting on expert companies on these types of technologies.
- Fully understand that in the cases where objective is to ubiquitous access to information and use these technologies exploiting their potential in collaborative working environments is basic, as well as with IoT, to have an infrastructure of communications being able to give an answer to the needs of this type of technologies.
- Last, to search integration with other systems that were being used in the company and that are part of the process as part of the productive process.

At the moment that we speak about the need of communication networks that allow access to data, we have to remind ourselves that it is a must that so named networks comply with all security standards that protects information.

8. DIGITAL TWIN. THE LINK BETWEEN THE MODEL AND THE REAL ASSET

Digital Twin is a widespread concept that belongs to the Industry 4.0 ecosystem but, what does it means and what is it for?. This concept means the connection between the real asset and the design, the virtual world.

There are industries where this concept is widely applied, but shipbuilding industry is still starting with it. Aero-generators, energy platforms, airplane engines are nowadays the most common cases where we can find Digital Twin applied to, with two possible approaches: create a Digital Twin of the product and create a Digital Twin of a complete factory and control the facility through its Digital Twin. An example is Azure Digital Twin, a Microsoft service announced by the end of 2018.

According to a Gartner´s study, Digital Twin is used by the 24% of the organizations with IoT technologies in production or with undergoing IoT projects and in the next three years, another 42% is planning to implement it.

Many technologies, most of them described in this paper, are necessary to make possible a real effective Digital Twin, but IoT could be considered the most important, without forgetting the most basic and important technology necessary to make the Industry 4.0 works, the communications infrastructure and, as always when we talk about data, security.

Digital Twin means a continuous and bidirectional exchange of Data between the real asset and the model, with the objective to have a real-time synchronization between those worlds.

Virtual to Real Asset data flow usually comes from a Control Centre that manages the data provided from the real world reflected into de virtual design. That Control Centre could interact with the real asset with a direct command executed through a console that will be converted in a digital signal that activates an actuator or by transmitting an order to a human operator.

Real Asset to Virtual data flow will be possible with a combination of sensors sending information through the communication infrastructure and human operators sending data by using Apps normally designed for devices that allow mobility and wireless connection.

Human or automatic processes, if the virtual asset includes AI or some automatic program that simply has an output depending on some input parameters, can manage both communication flows. At the basis of the Digital Twin, the model is a must. There are different ways to have it:

- 360-degree photographs: it is a 360º horizontal and 180º vertical photograph that can be reproduced in an interactive way into a 3D representation. This technology is the same used for Street View (google) available in Google Maps. There are special cameras that can take this kind of photographs, but it is also possible to generate a spherical photograph with standard cameras and specific software that can compose all those pictures taken from a fix position rotating the camera and taking all the necessary pictures to cover the complete surroundings. This is the most economical way to have a digital representation of the infrastructure. This solution is adopted when it is necessary to include the Digital Twin for Industry 4.0 purposes and there is no 3D model of the facilities. This solution is also the fastest one, but the quality of the results and the possibilities are much more reduced than the other solutions. One of the most obvious disadvantages is that it is not valid for taking any kind of measurement. This technology only provides a conditioned visualization and navigation environment since the possibilities of movement are limited to the movement from one sphere to other following specific directions. Nonetheless, it could be enough for cases where it is only necessary a navigable virtual environment where it is possible to attach information provided by sensors, for example.
- 3D Scanning: This method is widely explained in the paragraph that talks about 3D Printing.
- 3D CAD model: This is the best option for a new infrastructure, or for a facility that already has the 3D model that can be easily updated to current situation and be used as Digital Twin without excessive effort.

The combination of 3D CAD model and 3D Scanning is possibly the most interesting. With both technologies, it is possible to measure, and this is a very important advantage.

Shipyard is not a static scenario, that is why the best option is a Digital Twin based in 3D models generated with a CAD System and when necessary with models generated by using 3D Scanning technologies by transforming the clouds of points in volumes and surfaces.

This Digital Twin made of independent geometries, will be the best virtual environment to simulate and optimize processes, but also the best way to synchronize reality and the virtual world.

There are many applications for the Digital Twin and some of them are listed below:

- Remote monitoring and control of assets.
- Simulation of processes in a virtual environment.
- Training purposes.
- An updated 3D model of the facilities.
- Personnel, supply, assets real time control monitoring.
- Register of all the historical data and the possibility to analyse all that information in order to extract conclusions and decide actions to improve performance, for example.
- By combining historical data and algorithms, it will be possible to generate predictive models that can alert us about a dangerous or anomalous situation. The Digital Twin will provide the knowledge of all the dependencies between all the elements of the facility and the information about the monitored parameters. With that global information it will be possible not only the analyse situation of an asset but also predict the repercussions in the complete chain where that asset belongs to.

This concept can be implemented in an easiest way if all the stakeholders adopts Digital Twin; in fact, this is the real future of this concept, create a Plug and Play Digital Twin ecosystem. It means that an asset will be ready to be implemented into a Digital Twin facility in a natural way, just install the physical asset into the facility, make the login of the new asset into the data system to acquire the information that comes from sensors and include the 3D model provided by the vendor into the virtual facility. The

3D model will include properties, parameters a direct link to the information provided by its sensors and will include operational information and predictive models that will be working during its operational life in order to be possible an early detection of problems.

The Digital Twin of the asset will also include:

- Digital manuals to be consulted by using AR, infographic animations that provide step-by-step instructions for disassembly and inspection, etc.
- Programmed alerts for periodical inspections and maintenance operations.
- The possibility for manufacturers to link to the data of that asset, analyse its operating data to make real time recommendations and use that information to design new assets with improved characteristics.

An example of this Plug and Play ecosystem: if a Shipyard 4.0 needs storage racks, the provider of that asset will sold us a storage rack with its Digital Twin, which should include the 3D model to be directly implemented into the Digital Twin of the facility.

A fully equipped storage rack for Industry 4.0 should include, for example, RFID antennas to detect the RFID tags attached to the components that will be stored and those antennas will send the information of the quantity of stored components to a logistics application that will manage instantly the situation and take decision autonomously buying new components if necessary.

To reach this Digital Twin ecosystem the key factor is the definition of Standards, a common language to make possible an easy and fast integration of the real and virtual assets into a more complex Digital Twin.

All the possibilities provided by the Digital Twin lead to the real potential of this combination of technologies and processes that enhances greatly the future of shipbuilding. This gives the ability to always have an accurate picture of the vessel in real time by supporting and reflecting all the upgrades and modifications throughout the vessel´s complete lifecycle. No matter where you are, you know what happens in your real asset, thanks to all the information provided in your Digital Twin. All of this helps for better planning and efficient implementation of upgrades/modifications. Given that the Digital Twin provides a Digital Model, this is perfect environment for simulating all those changes prior to the implementation in the real vessel. This will reduce risks and provide the capability to define the best strategy for that implementation.

It is important to assume that a fully integrated Digital Twin is not always reachable and it will be frequent to find partial implementations that consists just in data acquisition from machines in order to analyse and use for different purposes, but once reached this first step, it will be easier to move in the Digital Twin direction.

9. A NEW GENERATION OF MATERIALS

Among one of the most defining technology trends is related to advanced materials. Advanced materials, referred also to as lightweight materials, are developed from compounds at a molecular level through applied physics, materials science, and chemistry. Advanced materials may generally be considered to fall into three categories, including metals, composites and polymers (typically fibre-reinforced polymers, is a composite material made of a polymer matrix reinforced with fibres, which are usually glass, carbon, aramid, or basalt), in addition to new materials, such as ceramics, carbon nanotubes and others nanomaterials. Nanomaterials are one of the main products of nanotechnologies which involve designing and producing objects or structures at a very small scale, on the level of 100 nanometres or less.

Overall advanced materials enable reduced weight of a product, component or system while maintaining or enhancing performance, operational supportability, survivability and affordability. When executed efficiently, weight reduction encompasses the early integration of design, development, and implementation of lightweight materials, component fabrication, assembly, joining, and other technologies, as well as the capability to manufacture and produce such materials and components at reasonable cost. Advanced materials increasingly important to the competitiveness of transportation manufacturing sectors because lighter vehicles have better performance and use less fuel. Subsequently, they can carry larger loads and travel the same distances at lower cost and with fewer carbon emissions.

The key objectives set out often by the research teams both in Europe and the US in relation to Carbon Fibre-Reinforced Polymer (CFRP) aim:

- To lower carbon CFRP cost.
- To ensure a reduction in CFRP embodied energy.
- To achieve a higher degree of composite recyclability into useful products.

Today's researchers and engineers are also finding a wide variety of ways to deliberately make materials at the nanoscale to take advantage of their enhanced properties such as higher strength, lighter weight, increased control of light spectrum, and greater chemical reactivity than their larger-scale counterparts.

Manufacturing at the nanoscale is known as nano-manufacturing. It involves scaled-up, reliable, and cost-effective manufacturing of nanoscale materials, structures, devices, and systems.

10. 3D PRINTING. A NEW WAY TO PROTOTYPE, FUNCTIONAL PRODUCTS AND MUCH MORE.

10.1 WHAT IS 3D PRINTING?

3D print is one of the technologies that can mean one of the main changes and more disruptive in the manufacturing value chain. It is a technology that allows a customization of the product never seen before, and in many cases is a real alternative to manufacturing technologies.

The impact is not only due to the way the products are manufactured, but the effects can also be seen in the way that the products are distributed and maintained. An example is the possibility of changing from stockage of a determined product with storage room occupation and aging until the moment it is used, to the printing of that product in the moment it is needed. We have examples in which 3D model is the purchase element, and then, with a 3D printer we can print it by ourselves as many times as necessary.

There are many 3D print types, but in general we can say that are techniques based on material addition layer to layer until model geometry is reproduced, while conventional techniques are based in subtraction, this is removing material by cutting, drilling or by means of moulding and normally several machines for the whole process are involved.

In 3D print there is a key factor, the 3D model, which origin can be from two different ways:

- Model made with CAD tools, particularly applications from those that are made for prototyping and conceptual design to those of mechanic CAD type: this is the more usual method for model creation that are going to be printed with 3D technology.
- 3D scanning: we find two main techniques:
  - Laser scanning.
  - Photogrammetry.

10.2 3D SCANNING TECHNOLOGIES

It is a technology able to reproduce with more or less precision a model or real environment in a digital environment through mapping to a physical version.

The most modern scanning techniques combine laser technology for the 3D points acquisition and photography to assign colours to those points and reproduce accurately the objects.

Depending on the scanner type, laser characteristics, boundary conditions, specially light and physical characteristics of the scanned object, influence in the quality and accuracy of the captured cloud of points, but if conditions are suitable, precision should be more than enough to give valid solutions for industrial applications.

Nevertheless, some other issues have to be taken into account when scanning:

- It can only be scanned what is seen by the scanner. This is very important, because all that cannot be reached by the beam, won't appear in the result. This means that if we want to scan all faces of an object, it will be necessary to position the scanner in different places for finally compound all points clouds in one.
- Having into account the previous, it is not possible to scan the inner part of an object.
- First phase of scanning is to obtain a cloud of points, but once done, the cloud must be simplified deleting unnecessary points, archives generated by the scanner are very simple, but the weight can be of importance, so the archives might be difficult to manage.
- After cloud simplification, these points are usually helpful if they are transformed in surfaces or volumes which can be worked; for doing so, as in the points simplifying, software is available in many cases provided by the scanner manufacturers that uses algorithms capable of assist end user to find certain basic volumes and surfaces, i.e. walls or spheres.

As can be seen, laser scanner usage is not easy, especially the part that refers to optimization of the cloud points and surfaces and volumes conversion.

In respect to photogrammetry, the process isn't easy as well, it requires a camera specially calibrated. Capture processes are similar to laser scanner, and also the conditionals, as the post-process until the 3D object is obtained.

In spite of difficulties and complexity of the process, these technologies are very useful, particularly and particularly could have great interest for:

- Inspection/ supervision processes.
- Perform comparisons between real model and scanned model, something that is used in industry such as automotive and aerospace to detect deviations with the original model especially in those cases in which accuracy in the manufacturing is critical.
- Reverse engineering.

The reconstruction of a digital model starting from a real model with these techniques makes sense if combined with 3D printing, as it eases the reproduction of pieces that need a quick repair in the cases that the reception of the original piece cannot be waited from a certain supplier.

The possibility of scanning a problematic element and combine the scan with the modelling of a solution that fits perfectly with the scanned for later printing of the solution is one of the biggest advantages that offers these technologies combination.

Once provided this solution and being tested in-situ, it is possible to create a piece manufactured by traditional methods by a supplier if the quality of the printed does not allow its use in operative conditions during the required period.

3D scanning has many other utilities in the CAD design, Digital Twin and simulation. Today, it is not unusual to find a combination of CAD models that integrate geometries obtained from 3D scanning. This is useful when modifying an engine room, for instance, scanning it and performing the re-design based in the 3D cloud points.

Digital Twin can as well source from 3D information generated by a CAD System as from the scanned information. A clear example can be found when it is necessary to have a Digital Twin and there is no 3D model available. 3D scanning is one of the possible ways to get Digital Twin without 3D modelling.

In respect to simulation, we can take back the engine room case and face a main equipment exchange as for example a generator or main motor. 3D scanning of the affected area will allow to generate a simulation that may define a strategy to face this operation from the best approach, by modelling tools and simulation of the different process stages combined with a system for collision detection.

10.3 3D PRINTING FUTURE

3D printing evolves very fast, although speed is not one of its qualities, in fact it is a critical point where development is focused. Among speed, the evolution of the materials that can be used in another key factor, as well as the size of the printed pieces. Plastic materials, biodegradable, etc. are suitable for prototyping, but not for completely functional pieces creation.

Sintered printers allow the printing of materials like aluminium, steel and titanium, materials that offer the necessary qualities for being used in common industry applications and machines and thus have a great potential within industrial sector. Sintered printing can be made in two ways:

- Direct sintering of the metal by laser Direct Metal Laser Sintering (DMLS): uses metal powder and it is the system with the largest potential in industrial area.
- Selective Laser Sintering (SLS): uses as base material plastic powder, or ceramic or glass.

We generally found metal materials as steel, Cobalt-Chrome. Aluminium, Titanium, or even Inconel, alloys that are normally used for high temperature applications. The resistance of pieces obtained is today similar to foundry or mechanizing techniques. Direct sintering is very used in aerospace industry, automotive and medical, i.e. for dental implant, and generally for prototyping and manufacturing of tools.

In 2018, Navantia created the first 3D printed piece installed into a vessel; it was the production of the cabins by means of this technique getting to print voluminous pieces thanks to an industrial 3D printer developed specifically for this project.

Printing with plastic materials has been proved interesting as well in pieces such as ventilation grids; this has been also studied by Navantia.

It can be said that 3D printing technique has been verified to be very useful reducing weight, material quantity and capacity for printing complex geometry, not possible to manufacture by conventional methods in one piece.

It is important to stand out that one of the biggest difficulties that arises when printing a 3D model is to configure the printer based on the material that is going to be used, quality of the pretended print end piece and the proper preparation of the model for its printing by one of these adding technologies. Periodic calibration of these printers is fundamental and depending on the type of printer chosen, factors such as ambient temperature can influence greatly in the process.

Industry like automotive and aerospace are the ones driving most of the progresses in 3D printing media, meanwhile in shipbuilding industry there is still a long way to make, challenges are very important and, in some cases, different to those that may exist in other sectors.

11. ROBOTICS

Robotics aims at the design, construction and operation of robots, in its broadest meaning. Many technologies are involved in the development of machines designed with the aim of replacing humans in some of their activities and the technological advances we are undergoing mean that more and more activities carried out by humans can be executed by robots.

This fast evolution makes increasingly frequent to debate the presence of this type of machines or systems and the substitution of human action by the action of the robot. More efficient, faster, free of errors, no need to rest... there are many incentives offered by the incorporation of robots in our processes.

Robots have been around for a long time and are especially susceptible to be used in repetitive processes or following some kind of more or less complex pattern. Especially useful are those that allow the human being to be freed from dangerous tasks, such as carrying out work in hazardous environments or situations.

Activities in industrial environments, such as a shipyard, are often dangerous and the use of robots to carry out such operations is highly desirable. With the arrival of AI, a strong change has been made to robotics, allowing it to extend its field of action also to situations in which decisions must be made based on the contour conditions that the robot is able to detect with its sensors and elaborate a response to that situation on its own.

The applications of robots are huge and growing as technology and materials advance, but some of the main applications are:

- Robots for military applications: it is in the military field where we can find greatest progresses, with bipedal robots, quadrupeds, etc. as those developed by Defence Advanced Research Projects Agency (DARPA). These devices can carry out a wide range of operations that complement, and in many cases replace, the direct action of human manpower.
- Robots for industrial applications: Within the industry, the automotive sector is the one that most often uses robots in its production plants, reaching in some cases such high levels of automation that manpower hardly participate.

Although this is not classical robotics, understood as a programmable machine with the ability to interact with physical elements and perform different operations, we can also treat as robots the Robotic Process Automation (RPA).

A RPA consists in the application of artificial intelligence to processes so that a robot software or bot can reproduce the way in which a human interacts with a computer. This robot is capable of interpreting and reproducing these operations by itself, even incorporating into its operation the different paths that a human can follow based on events or parameters defined in the process, in order to be able to make decisions and even improve them if learning techniques are implemented.

This type of robots are analogous to the traditional ones, but in this case, replacing the human activity in the ecosystem of a software.

In the case of a shipyard, as in any other industrialized field, there are an infinite number of activities that are currently carried out by humans and which, due to their repetitive and 100% parametrical nature, are perfectly capable of being carried out by bots.

The technology exists, and it is in constant evolution, waiting for all the processes to be analysed and to determine which of them can be carried out in an automated way.

This means, both for the classic robot and the RPA robot, which the human worker will in many cases be replaced by robots, but this does not mean that the human is no longer necessary. These technologies bring with them new types of work and the human must occupy the space to exploit their true potential and not underuse their capabilities in repetitive and monotonous tasks. That makes a lot of sense, but it is certainly a drastic change and assimilation can be complex, but if there is one thing that human beings have demonstrated, it is their capacity to adapt.

The main objectives that the industry aims with the implementation of this type of automation technologies can be seen in Figure 13.

It is also interesting Figure 14, that shows what technologies the industry is focusing on right now.

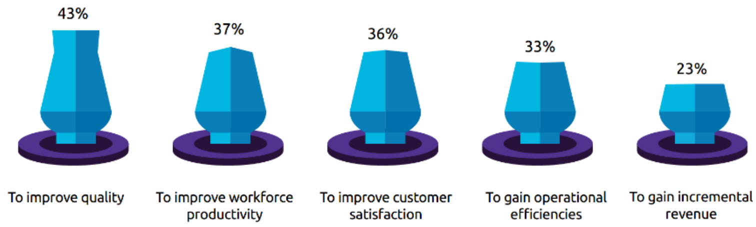

Figure 13: Main objective behind automation initiatives among organisations experimenting with or implementing automation (Capgemini Research Institute, 2018a)

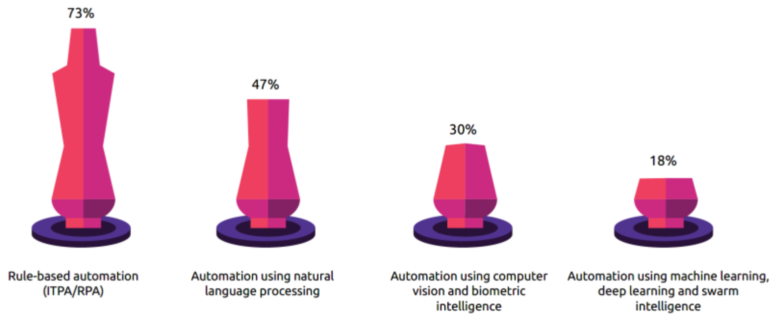

Figure 14: Current focus on automation technology among experimenting with or implementing automation (Capgemini Research Institute, 2018a)

The implementation of these technologies means facing important challenges for a company, since adopting them will imply important changes at all levels, organizational, processes, people, etc. That is why is very important to make a deep analysis in order to define a strategy that allows the best adaptation.

A key factor for the correct implementation is the standardization and optimization of business models before these types of technologies come into play. The more orderly and clear the processes, the more effective this technology will be. In diffusely defined processes, automation is not an option.

Beyond these two types of robots, exists a type of technology that could be included in robotics and, in the industrial field, especially in the environment of a shipyard, can have a brilliant future.

We talk about devices that enhance human capabilities when carrying out their activity. It could be said that a person endowed with a Google Glass type device, which allows access to contents superimposed on reality, is equipped with a device that enhances its capacity through access to information invisible or inaccessible to someone who does not have that device. This gives the advantage when performing certain jobs in which access to that information enables the user to perform tasks more efficiently and safely, but this is not the type of robotic device to be treated it is the exoskeletons.

These devices are capable of multiplying capabilities such as the strength of a human being, something that can be especially useful when working with large and heavy pieces, such as those that can be found in a shipyard or facilitate the performance of tasks that require forced postures.

It seems like science fiction, but it is a technology that is present and that is also improving at a good pace, although its application is still limited and mainly at the prototype level.

Important advances have been made in the military field, but good examples can also be found in medicine, such as devices that allow people who have never been able to get back on their feet, have suffered accidents or degenerative illnesses that have put them in a wheelchair.

One of the main difficulties faced by this type of devices is the autonomy; many of them require external power, as the weight of the battery for having a minimum operating autonomy makes it unfeasible, so advances in the field of batteries are essential to have really useful exoskeletons. Some examples of this technology:

- Raytheon XOS 2 Exoskeleton: exoskeleton developed for military purposes that allows the user to lift and carry heavy weights without loss of agility (army-technology.com).
- Berkeley Lower Extremely Exoskeleton: This exoskeleton system is designed for soldiers, disaster relief workers, and other emergency personnel and provides the ability to carry heavy loads with minimal effort over any type of terrain for extended periods.
- An industrial application of this type of exoskeleton can be found in the Spanish company Telice, a company in the railway sector. In March 2019 they tested two exoskeleton models that fit to the worker's body allowing him to handle easily heavy parts, perform tasks in forced postures that thanks to this armour required less effort. These exoskeletons do not make the worker stronger, but its principle of operation is based on a better distribution of muscle's load. Its use by operators who perform repetitive tasks, work with heavy parts or need to keep postures that produce strong joint and muscle wear, allows them to improve their working conditions and reduce the chances of injury and with it, medical leaves.

Exoskeletons promise to be important in the Industry 4.0 and in particular in the Shipyard 4.0 since the conditions for considering their use in shipbuilding are evident.

12. THE FUTURE OF THE VEHICLES

We have all heard about autonomous vehicles that promise to change the way we move. Although we may already find vehicles capable of driving autonomously, much remains to be done, both technologically and regulatory.

In the industrial field, the objective sought with this type of vehicle is to improve logistics and the transport of materials in the factory itself; or in our case, the shipyard.

Autonomous vehicles that are already used in industrial environments use different types of navigation systems, so we can distinguish two types of autonomous vehicles based on the navigation system they use:

- Self-Driving Vehicles (SDV): these are the most modern and have sensors, Lidar sensors, 3D laser scanning, that allow them to move completely autonomously and generate a map of the environment, just as robots vacuum cleaners do today.
- Automated Guided Vehicles (AGV): have navigation systems based on magnetic tape, beacons or additional infrastructure to follow its path around a facility.

For these vehicles, it is essential to have a robust communications infrastructure that allows dialogue between vehicles, as well as with the system that transfers precise instructions on what to transport, where to pick it up and where to take it.

The implementation of this type of vehicle in production processes has been shown to provide significant cost savings, although it is true that the necessary investment may be a factor that does not offset the expense.

These autonomous vehicles are widely used in the automotive industry or large logistics centres, but is the shipyard a good place to use them?. The transport of materials from one point to another is where this type of technology can add value, but for proper operation of these vehicles it is necessary to have space, cleared roads and a lot of order.

In an environment such as a shipyard, SDVs are the vehicles that have the greatest possibilities of being able to work properly due to their capabilities. Those capabilities are mainly provided by the sensors that allow navigation with a dynamic analysis of the environment, the detection of obstacles and the intelligence to avoid them, as well as a dynamic planning of the route to follow.

The distribution and the way of working in a shipyard is far from what can be found in a car factory or a large logistics centre, environments with a clear definition of spaces. In both cases, it is feasible to reduce interference between humans and autonomous vehicles. The implementation of autonomous vehicles in a shipyard may not be feasible if minimum conditions are not met so that these types of devices cannot move properly and, in any case, only SDVs seem to be viable.

It is also important to comment on an important functionality of this type of vehicle: the map of the working environment generated thanks to the Lidar can be edited to mark on it different types of areas, such as areas through which it should not circulate, for example.

Recent advances in SDVs make autonomous vehicle-human compatibility in the same working environment increasingly feasible.

Examples of this type of vehicle are: Otto1,500 model with a load capacity of 1,500 kg and Otto 100 with a load capacity of 100 kg (ottomotors.com).

In the area of inspection, the use of multi-copter air drones equipped with cameras and sensors to avoid collisions is another possibility on which work is being done. The internal inspection of large cargo tanks or the monitoring of the evolution of the construction from an aerial view can be good application examples.

If we add photogrammetry, it is possible to make 3D models with multiple uses, like for example the possibility of carrying out an analysis of the evolution along time of the construction of a ship, something that is already being used to monitor the evolution of a land construction, for example, or to calculate volumes.

It is important to know the way in which these drones are handled. Normally there is a pilot drone that operates the vehicle, but it is foreseeable that drones will be able to work autonomously sooner or later in confined environments, just as at this moment autonomous outdoor operation is feasible thanks to GPS positioning and the possibility of planning flight routes that they carry out completely autonomously.

Other aspect when we talk about autonomous vehicles is the way these vehicles can condition the design of the future ships, especially warships.

To operate drones from warships or other kind of vessels, it is necessary to enable operative space on board, space for the complex systems that could require to control and operate these kinds of vehicles.

Another factor that adds complexity is the rapid and constant evolution of the technology of those vehicles. The design of the ship should also consider the possibility of changing those vehicles and that means different operative space and different systems to operate. These requirements have to be satisfied in the vessel design and engineers should be able to provide the solution for these requirements. The answer is the modular concept and CAD Systems that can provide the necessary tools to work with this modular concept (Pérez and Péter, 2019).

13. CONCLUSIONS

After the revision of all this technology, it is likely to have a hint of the enormousness and difficulty of the variations that Industry 4.0 is challenging.

13.1 KEEP COMPETITIVE

To keep competitive it is an unavoidable step to continue reviewing what there is in the market, and in many cases to adopt part of what it is revealed in this paper. Before to try to implement any of the technologies mentioned, it is necessary to study carefully what it is required, because it could be complex and dangerous. Although some of these technologies are in not mature enough for a business implementation, it is essential to be conscious and examine what they could propose or suggest in any particular occasion.

13.2 WHY NOW?

The majority of the technologies shown before are not new and known since years ago, some from decades; however, the real potential has arrived after the enhancements in the hardware and infrastructure, so concepts as Digital Twin are now accessible and viable. Today with 5G technology, it is estimated that IoT will arise in all his powerful and it will be developed in an exponential way, providing a huge impulse to other technologies as the Digital Twin.

In any case, although 5G and WiFi promises to be the definitive impulse for IoT, not all the cases could be solved with this technology, or at least, only with this, so it will be necessary to study carefully the conditions to decide the best communications infrastructure or even conclude that there is no feasible solution. Shipyards and ships are both cases where the conditions are not favourable for IoT deployment, particularly because of the important presence of metallic materials, one of the worst allies for WiFi communications. The highest the frequencies are, the worst WiFi behaviour will be in spaces surrounded by metallic materials, and this means that 5G and WiFi 6 should be studied carefully for these cases or similar ones. Therefore, the first challenge for a correct implementation of Industry 4.0 technologies is the network.

Platforms like Raspberry PI, Arduino and others, were key factors for the evolution of IoT technologies and its democratization thanks to an innovative ecosystem where all kind of developers, Universities and Companies were able to contribute to the IoT evolution. This is maybe the second main factor for the Industry 4.0, the IoT technology is more accessible, both economically and technically for companies and persons, but IoT will reach its full potential when a true standard is stablished, a common language that makes easier for developers to create IoT devices, exchange information, and create infrastructures easily scalable and sustainable.

There are many technologies, as VR, which have reappear mainly because of the video-games business and the reduction in the cost of acquiring equipment items due to the progress in the reduction of the size among others. VR has an extensive use for training, simulation and checking purposes, however the AR implementation has a much more interest for companies.

Ubiquitous access to information, immediacy, and remote operation of assets … nowadays these possibilities are in the hand of everyone, and this means a deep change in the Industrial world but also for the human being.

13.3 ARE OUR INDUSTRIES, INFRASTRUCTURES AND PRACTITIONERS READY FOR THESE TRENDS?

We are experiencing an incredibly rapid technological evolution that leads to an exponential growth of data acquisition that needs more and more storage space, and IoT will increment the data inputs that, with the new 5G, it is expected to become even more.

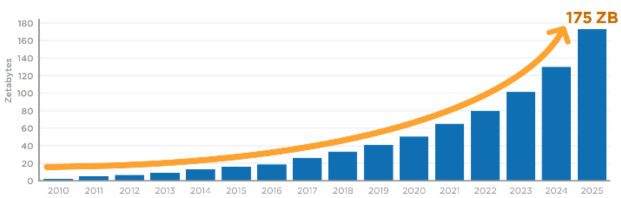

Figure 15: Annual Size of the Global Datasphere (IDC, 2018b)

According to a report by the IDC consultancy the data volume will reach 175 Zettabytes in 2025 which means 175 times the information generated in 2011 and the growth is exponential, as can be seen in the Figure 15.

The report ensures that the most of this information will be stored in the cloud and confirms that biggest contribution to this enormous increment of that will be a consequence of more than 150,000 million of devices connected to the network, in other words, IoT.

This perspective reinforces the ideas explained in this paper about the experience in the e-Flow project that describes the importance to filter the relevant information from the origin, by pre-processing the information in order to store only the useful information or simplify by using some kind of codification.

Another representative information provided by this report is about the intensity with which the people will interact with connected devices, 4,800 interactions/day in 2025, which means practically a permanent connectivity through the network; a big jump from the 1,426 interactions/day expected for 2020.

13.4 CONNECTED WORLD AND THE CONNECTED HUMAN

This entire connected world is a natural environment for the new and future generations and this means that the future workforce will be totally immersed in these technologies and they will be dependent on it.

In the not too distant future, it is possible that the concept of transhumanism becomes a reality, in a certain way we are already living the approach to that new reality because an enhanced human is what we are creating with this technological evolution. Devices like exoskeletons, google glass… are changing the human capabilities and here is another important actor of the entire Industry 4.0 ecosystem, the devices that allow persons to be connected to the data. Smartphones will be soon obsolete devices, all the connection possibilities will be available through other kind of devices, more natural and integrated, something like google glass and of course, AR and MR will be the technologies that will enhance our link with data by overlapping reality and data.

13.5 OTHER KEY FACTORS

The security is another key aspect, as well as the authenticity and accuracy during the transactions of data and information between all the partners. The data communication must be ensure and certify (through blockchain for example), tracking every transaction.

One of the most important element of the shipbuilding environment is the CAD system. This type of tools should be linked to these technologies (i.e. 3D printing), adapting them to new demands as modern interfaces between different tools. The main product of the CAD is the 3D model, the core of the Digital Twin, which is the connexion between the computer-generated world and the reality.

The Industry 4.0 is ready and Shipbuilding is one of the areas with more room for improvement. The future is promising, and it is mandatory to analyse how these tools could expand the advantages to remain competitive. We have the technologies, however it is essential to review and evaluate each specific situation. There is not a universal solution for each industry, however these technologies are in our hands and sufficiently mature to initiate the implementation in our sector.

14. REFERENCES

1. BENAYAS-AYUSO, A. and PÉREZ FERNANDEZ, R. (2018). *Automated/controlled storage for an efficient MBOM process in the shipbuilding managing the IoT technology*. SMART SHIP, 23 and 24 January.
2. BENAYAS-AYUSO, A. and PÉREZ FERNÁNDEZ, R. (2019). *What should shipbuilding expect from the CAD/CAM systems of the future?*. The Naval Architect magazine. April. pp. 28-31.
3. CAPGEMINI RESEARCH INSTITUTE. (2018a). *Rashing the future: unlocking automation´s untapped value*. *www.capgemini.com* (Last visited: October 2020).
4. CAPGEMINI RESEARCH INSTITUTE. (2018b). *Augmented and Virtual Reality in operations: A guide for investment. www.capgemini.com* (Last visited: September 2020).
5. GOOGLE. *google.com/glass/start*. (Last visited: June 2019).
6. HOLZ, D. (2013). *Systems and methods for capturing motion in three-dimensional space*. Patent No.: US 8,638,989 B2.
7. HURWITZ, J.; KAUFMAN, M. and BOWLES, A. (2015). *Cognitive Computing and Big Data Analytics*. John Wiley & Sons, Inc, Indianapolis, Indiana, USA. ISBN: 978-1118896624.
8. IDC (2018a). *Worldwide Semiannual Internet of Things Spending Guide 2018H1*. *www.idc.com* (Last visited: December 2019).
9. IDC (2018b). *The Digitization of the World from Edge to Core*. *www.idc.com* (Last visited: December 2019).
10. IMT ATLANTIQUE. *imt-atlantique.fr* (Last visited: June 2019).
11. INTERNATIONAL TELECOMMUNICATIONS UNION. (2018). *Key features and requirements of 5G/IMT-2020 networks*. ITU Arab Forum on Emerging Technologies. Algiers. 14-15 Feb.
12. IoT ANALYTICS. *iot-analytics.com* (Last visited: June 2019).
13. LEAP MOTION. *leapmotion.com*. (Last visited: June 2019).
14. MAGIC LEAP. *magicleap.com*. (Last visited: June 2019).
15. MICROSOFT. *https://www.microsoft.com/en-us/hololens/hardware*. (Last visited: June 2019).
16. MUÑOZ, J.A. and PÉREZ FERNANDEZ, R. (2017). *CAD tools for designing smart ships in the world of the Internet of Things*. SMART SHIP 2017, 24 and 25 January.
17. NAKAMOTO, S. (2009). *Bitcoin: A Peer-to-Peer Electronic Cash System*. Cryptography Mailing list at https://metzdowd.com.
18. OTTO MOTORS. *ottomotors.com*. (Last visited: June 2019).
19. PÉREZ FERNANDEZ, R.; Benayas-Ayuso, A. and Pérez-Arribas, F. (2018). *Data management for smart ship or how to reduce machine learning cost in IoS applications*. SMART SHIP, 23 and 24 January.
20. PÉREZ FERNANDEZ, R. and PÉTER COSMA, E. (2019). *The use of CAD systems to manage modularity in multi-role warships*. RINA Warship Conference, Bristol, June 2019.
21. PÉTER, E. (2014). *Modelo Híbrido para la Ayuda al Capitán*. PhD Thesis. ETSI Navales (UPM).
22. PÉTER, E. et al. (2014a). *e-Flow - Sistema Integral Inteligente de soporte a la evacuación (1 part)*. Ingenieria Naval. No. 924. pp. 87-95.
23. PÉTER, E. et al. (2014b). *e-Flow - Sistema Integral Inteligente de soporte a la evacuación (2 part)*. Ingenieria Naval No. 925; pp. 72-87.
24. RAYTHEON´s XOS 2. *army-technology.com*. (Last visited: June 2019).
25. VIVE. *vive.com*. (Last visited: June 2019).
26. VR GOOGLE. *vr.google.com/cardboard*. (Last visited: June 2019).