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How the Industry 4.0 could affect the shipbuilding world

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ABSTRACT

The marine structures are developed with Computer Aided Design (CAD) platforms, but every day we are looking for integrated development of the product involving all its Life Cycle. CAD system integrated with Product Lifecycle Management (PLM) and from the PLM we can conceive all the design but also control the production and include the use of the vessel. The PLM can contain information of all systems of the vessel and also all its components. If the components are designed for the Internet of Ships (IoS) it will have technology that allows to share their situation, diagnosis, functionality with the PLM system which distributes the initial design. The PLM system can use this information for knowing whether they are working properly or if we can improve its performance. It is also possible to identify whether it is necessary to make maintenance of the object or if it is necessary to replace it because its life ends or because it's working wrongly. It will be possible to determine and evaluate its performance comparing to other similar components or comparing to it different operating periods. It will also be possible to know how their performance affects the functioning of the whole product, i.e., the vessel. Furthermore, if the connection of the objects is realized with its PLM, it would be possible to record their history status, make change tracking, and know what is its function or its performance after realizing programmed maintenance. In case of a vessel, this connectivity will be extended to the commercial mission to act autonomously in operation conditions. A commercial vessel can transmit its navigation situation, load situation, the things to be discharged or to be recharged. All these means a huge amount of information to be managed and analysed. New programs have to be developed to obtain the best use of such information so that the design can be improved from real function information of the design and it can be self-maintained with the connection with this huge cloud information to create method that the objects can achieve certain "Intelligence".

The growth of the IoS is linked to the increase of Information and the management of Big Data, with the property that somehow IoS identifies Information and direction and order to a specific purpose, while the concept of Big Data is more generic. The possibilities are countless, but the beginning is the same. It must begin in the initial design. It is necessary to consider what is needed to correctly fulfill the mission of the atomic elements. These requirements must be configurable in the initial design from where it will be extended to relations between each of them with other entities. CAD is one of the first steps, because it is where begins to collect systematically the concept of each component. Therefore, the aim of the paper is to explain why it is necessary to provide CAD tools to carry out the design for IoS.

1. State of the art as regards Industry 4.0.

The *Industry 4.0* transformation implicates a huge collection of interrelated and joined technologies, which can be analysed independently, but must be applied as a complete integrated implementation in each industrial field, moreover, in the *Computer Aided Design*, *Manufacturing* & *Engineering* (CAD

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/ CAM / CAE), from now on referred just as *CAD*, and *Product Lifecycle Management* (PLM) development industry. Each technology exposes a set of boundaries which cannot be differentiate evidently from its neighbouring technology.

Virtual Reality, *Augmented Reality* and *Mixed Reality* are closely associated to the *Digital Twin* and interconnected with the *Big Data*, which is produced by the *CAD* tools and all surrounding solutions, which applies some *cloud/edge/fog* computing to this data in a merged technology between finite state machines and *Artificial Intelligence* cognitive processes [Benayas-Ayuso & Pérez Fernandez, 2018].

To perform in an agile manner all these computing, it requires a network which support different connection ways to add special devices, i.e. *Internet of Things* (*IoT*), which can access to the data, creating and modifying it, in a different layer which affects to the basic information layer created by the *CAD* System in the shipyard.

This network should be secured, *cybersecurity*, but open to allow distributed work, which must be step controlled in a manner that records any modification of each working step done in an open, transparent, trusted and non-modifiable working method for all actors involved in process, like: shipyard, engineering offices, classification society and ship owner, *blockchain*.

Results of the design should be easy integrated with future building ways like *3D printing*, generating printing orders directly from the *CAD* model or from the *PLM*.

Shipbuilding engineering phases involve design and production, but an integrated *Industry 4.0 CAD* System should also be involved in operation and maintenance.

When a ship comes for a reparation, sometimes the model is not available for this operation of maintenance.

In repair and maintenance steps, replicating the full engine room or any other compartment in the *CAD* System could be a nightmare, unless *CAD* tool has an *Artificial Intelligence* processing toolkit which, from a cloud of points, can recreate *CAD* equivalent items which can be converted with a minor user intervention, and lesser as the *Artificial Intelligence* learns, in a *CAD* integrated and full modifiable design.

At the end, this is just a short summary of the *Industry 4.0* technologies, which can be applied to a *CAD* System (as shown in *figure 1*), included in, or as an integrated surrounding solution, or as information producers for the evolutive design process.

To be able to understand how *Industry 4.0* became today's buzzword, a look at its predecessors might give us a perspective on how this revolution in particular is different.

- **The First Industrial Revolution**. The industrial revolution in Britain came in to introduce machines into production by the end of the 18^{th} century (1760-1840).
- **The Second Industrial Revolution**. It dates between 1870 and 1914, although some of its characteristics date back to the 1850, and introduced pre-existing systems such as telegraphs and railroads into industries.
- **The Third Industrial Revolution**. It is much more familiar to us than the rest as most people living today are familiar with industries leaning on digital technologies in production.
- **The Fourth Industrial Revolution**. It takes the automation of manufacturing processes to a new level by introducing customized and flexible mass production technologies.

Figure 1: Related Industry 4.0 Technologies in a Shipbuilding CAD environment.

Source: Benayas-Ayuso and Pérez, 2019.

2. Internet of things.

2.1. Challenges of the IOT.

The success of *IoT* will only be possible if the initiatives have a clear component oriented to the business. It is necessary to identify which of the initiatives provide a clear value to the business, but taking into account that this value can be in various terms and not all directly economic. The clearest ones have to do with the optimization of energy costs, fuel consumption, choice of routes, safety at sea, but also in the work itself inside the ship [Muñoz & Pérez Fernandez, 2017].

One of the conclusions of all the analysis about the consequences of the *IoT* is that objects must be re-thought from the early design.

The fact is that ships are subject to harsh environmental conditions makes that any technological advance to be applied inside a ship have to take into account from the very beginning. Currently all the designs in the modern society are made by information technology tools, computer aided designs, supported with adequate databases and with lifecycle management of the information. To address the challenge of the *IoT* for ships, it is necessary a new concept, the *Internet of Ships* (*IoS*).

2.2. A new concept. The Internet of ships .

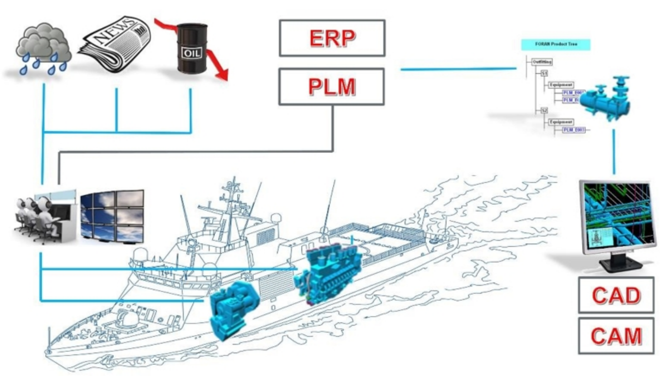
It is estimated that in 2020, 25 billion of devices will be connected to Internet [Kirsch, 2015]. This revolution that began a few years ago has aroused enormous interest in all industries and in some of them already works with apparent normality.

Nowadays it is possible to order directly from our refrigerator as soon as it detects that we need our regular products or smart lamps that light up alone when needed lighting. The world go on steadily toward what will be undoubtedly one of the most important revolutions in the history of humanity.

We could define the *IoT* as consolidation through the network of networks a "network" that staying a multitude of objects or devices, that means, to connect all things of this world to a network, we are talking about vehicles, appliances, mechanical devices, or simply objects such as shoes, furniture, luggage, measuring devices, biosensors, or anything that we can imagine.

At its core, *IoT* is simple: it's about connecting devices over the internet, letting them talk to us, applications, and each other. But *IoT* is more than smart homes and connected appliances, however. It scales up to include smart cities *think of connected traffic signals that monitor utility use, or smart bins that signal when they need to be emptied* and industry, with connected sensors for everything from tracking parts to monitoring crops.

Figure 2: Ideal representation of a 3D model with access to the different ship design disciplines monitoring crops.



Source: Authors.

In this context the question is if the naval sector is ready for this revolution. Is it possible that this traditional and conservative sector moves into this technology? There is already evidence that the shipbuilding industry is no stranger to these developments and is already connected to the Internet some components of ships, as it is exposed on figure 2.

As there smart home or smartphone, there are new smart ships that will be equipped with a network of sensors that capture a range of voyage information, including location, weather, ocean current, status of on-board equipment and status of cargo.

Ship owners can monitor the vessel's status in real time and apply analytics to current and historical data to make decisions that enable them to run more efficiently, saving time and fuel.

Sensors and *Information Technologies* are facilitating the introduction of new applications at sea, like energy distribution, water control and treatment, equipment monitoring in real time… The aim is to take this technological revolution also acting in the design and production phases in order to build efficient, safe and sustainable vessels.

In a decentralized sector, like naval, where often the engineering and production are in different locations and where critical decisions cannot wait, the *IoS* or connection through the network of critical components in the design/shipbuilding, starts to glimpse as something that the sector cannot obviate.

The idea is to monitor all those parts in which early detection of events allows us to make the right decisions. In this sense, the available sensors during the early stages of construction of the ship, allow us to identify if the construction of the boat is completely according to the design we have created with *CAD*. If we can reduce materials or use another material, if we must change anything according with naval architecture calculations… The continuous monitoring integrated with a naval design *CAD* will reduce costs and avoid mistakes and make decisions in real time from the shipyard, design offices or from remote locations.

Nowadays *CAD* and *PLM* solutions can be used in a pocket tools, making it the indispensable ally in this new technological revolution.

Shipbuilding process, generates a lot of information and data, which a priori makes it seem impossible to have all this data in real time, but the new processors, simpler and smaller, with a good connection to the Internet, make it possible.

The data management is, however, only one side of the coin of the *IoS*. Energy efficiency is a fundamental aspect also in new devices that connect to the network.

But *IoS* not only covers the stages of design or production of the boat. Once the sensors are in the components whose information want to monitor, we will be able to obtain information throughout the life of the ship.

IoS is presented as a solution capable of detecting when a component on a boat is close to fail and must be replace, when we take the boat to repair when we have to paint again, when corrosion has reached a certain limit ... and all this from our pocket tool and early enough to avoid late or unforeseen performances. *IoS* reaches this sector to ensure profitable production, or safe, efficient and sustainable process for all types of fishing vessels, tugboats, tankers, charges, ferries, dredgers and oceanographic...

3. Simulation.

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

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

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.

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 *Virtual Reality* and *Augmented Reality* 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 Fernandez et al., 2018] 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* or *PLM* 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.

4. Autonomous 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, *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.

Recent advances in *SDVs* make autonomous vehicle-human compatibility in the same working environment increasingly feasible. Examples of this type of vehicle are: *OTTO1500 model* (as publicised in *figure 3*) with a load capacity of *1,500 kg* and *OTTO100* with a load capacity of *100 kg*.

Figure 3: OTTO 1500 can be equipped with a conveyer belt.

Source: 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.

5. 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.

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 (*google.com/glass/start*), 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 (revealed in *figure 4*) developed for military purposes that allows the user to lift and carry heavy weights without loss of agility.
- *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 could be used 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.

6. Artificial Intelligence.

Control system in the ship can include some *Artificial Intelligence* 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 Fernandez 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

Figure 4: Soldier wearing Raytheon's XOS 2 .

Source: www.army-technology.com.

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 *Artificial Intelligence* 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.

Artificial Intelligence 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 & Pérez Fernandez, 2019].

Ship operation phase is not the only one which produces a set of *Big Data* to be processed by an *Artificial Intelligence* 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 Artificial Intelligence* tools, can be classified generating working sequences, design automatic checks, and automatic design processes.

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

Artificial Intelligence 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 *Artificial Intelligence* System.

To improve it, some other technologies can be applied, like Cognitive *Artificial Intelligence*, which is the base of natural language processing in an *Artificial Intelligence* solution. This cognitive *Artificial Intelligence* 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 *Artificial Intelligence* tool. All *Artificial Intelligence* 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 *Artificial Intelligence* 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.

7. Advanced 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.

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.

8. 3D Printing.

3D printing 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 and photogrammetry.

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 of points*. *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.

3D printing evolves very fast, although speed is not one of its qualities, in fact it is a critical point where development is focused.

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.

9. Digital Twin.

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*.

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. *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 *Artificial Intelligence* 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:

- **Spherical photographs**: it is a *360º* horizontal and *180º* vertical photograph that can be reproduced in an interactive way into a *3D* representation.
- **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 perhaps 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.

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.

10. Cloud and Cybersecurity.

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].

11. Blockchain.

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* or *PLM* 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*.

12. Virtual Reality and Augmented Reality.

Both *Augmented Reality* and *Virtual Reality* are technologies that cannot be considered as new, especially *Virtual Reality*, whose origins go back to the *Second World War*. Until not long ago, the use of *Virtual Reality* 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, *Virtual Reality* and *Augmented Reality* have revived. Today, and thanks to the possibility of using smartphone for watching/interact in *Virtual Reality* environments or visualize *Augmented Reality* contents, these technologies are available to everyone without need of having a very powerful device.

Nevertheless, *Augmented Reality* 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*, *Virtual Reality* and *Augmented Reality* comes along and *Digital Twin* is an unstoppable wave in *Industry 4.0* and *Shipyard 4.0*.

Augmented Reality application in Industry could be wide, and in part also offers many of the possibilities that *Virtual Reality* proposes but it is necessary to distinguish in each case what is the best option. *Augmented Reality* has a strong link with reality; this doesn't happen the same way with *Virtual Reality*, but if this *Virtual Reality* 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*. *Augmented Reality* 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 *Virtual Reality* 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*.

Conclusions.

As an example of *IoS*, the connectivity in smart ships will be extended to the commercial mission to act autonomously in operation conditions. A commercial vessel can transmit its navigation situation or its loading conditions. All these means a huge amount of information to be managed and analysed. New programs have to be developed to obtain the best use of such information so that the design can be improved from real function information of the design and it can be self-maintained with the connection with this huge cloud information to create method that the objects can achieve certain intelligence.

The growth of the *IoS* is linked to the increase of information and the management of *Big Data*, with the property that somehow *IoS* identifies information and direction and order to a specific purpose, while the concept of *Big Data* is more generic.

Last advantage is, if something happens in a ship, it can be reproduced in the shipyard based on this model, and getting a full condition simulation. This helps to focus the problem.

Adding some *Radio Frequency IDentification* (RFID) tags to the parts, can improve system information in ship brain, and if some parameters can be improved due to new known experiences can be downloaded in the ship to improve her behaviour.

After the review of all this technology presented in the paper, it is possible to have an idea of the magnitude and complexity of the changes that *Industry 4.0* is demanding. In most cases, it is an unavoidable step that must be taken to remain competitive, but with the adoption of only a part of what is exposed; it could mean a too risky and complex step that should be studied carefully before taking any decision. Some of these technologies are in early stages for industrial implementation but it is important to be aware and analyse what can offer and what can be useful for each case.

Most of the different technologies exposed in this paper are well known since long, but the true potential came a few years ago with the improvements in the communications infrastructures, that is why a concept like *Digital Twin* is something that seems reachable. Now with *5G*, it is expected that *IoS* will grow in an exponential way and its true potential will arise, which will also mean the *Digital Twin* impulse.

The *Virtual Reality* technology have reappeared mainly thanks to the Game Development Industry and the lower cost of technology derived from the evolution of flat screens and miniaturization among other factors. *Virtual Reality* seems to have an important future for training and simulation purposes, but its implementation in companies has a lower interest compared with *AR*.

There is another important piece of the puzzle: the security, veracity and trust in the data transactions between all the different participants. *Cloud* and *security* are two pieces of the game and without them, all this ecosystem will never work. Data transactions should be guaranteed and all the steps should be tracked from the first step to the last one of the process thanks to *blockchain*.

Repetitive tasks and dangerous activities that nowadays are carried out by labour force, can be replaced or supported by robots, which means an important change for the companies and the people that works there, but this transformation is unstoppable. New jobs will be created and new profiles will be necessary but those jobs that could be replaced totally or partially with robots will disappear. People should react to this new conditions and adapt.

The implementation of robots and autonomous vehicles in the Industry will also mean the presence of new tools that will improve working conditions for current workers, but it is necessary an adaptation to all these new technologies and sometimes it will not be easy. Shipbuilding is an Industry that could take advantage by using them, but depending on the particularities of each shipyard, this technology will be more or less easy to implement and even if it is feasible, the decision should be taken with perspective, because physical robots and autonomous vehicles needs special conditions to work.

New materials and *3D printing* techniques will have an important role in the future of Shipbuilding as is already being demonstrated in other industries such as aeronautics and automotive but in shipbuilding there are interesting challenges, the use of *3D printing* on board.

In the middle of this ecosystem we will find a *3D model*, created mainly with *CAD* tools and this means that the importance of *CAD* will be even more capital than today. The interface between the *3D model* and the rest of the *Industry 4.0* is the *Digital Twin*, the link between the reality and the virtual world, both living concurrently during the evolution of the construction and extending this world of possibilities to the entire lifecycle of the product.

CAD and *PLM* tools, as an important part of all this environment, should also evolve to be easily linked to these technologies, but also it is important to be adapted to the new generation of users that demands a different kind of interfaces and workflow and this will require an important effort.

This big world is now open and Shipbuilding is starting in it, but the potential is clear and to remain competitive is mandatory to study how these technologies can improve the benefits by upgrading processes, resources, workflow, cooperation between stakeholders... the tools are here, now it is necessary to study and analyse our particular case. There is no global solution for all industries, not even a global solution for a particular industry, but digitalization is on hand and it is mature enough to start implementation and be part of our strategy for the future. .

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