Design Rules Evaluation through Technologies of Treatment of Big Data

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Abstract

New technologies are appearing in the world that very shortly shall be linked with the design solutions in order to facilitate the same design by providing additional capabilities that were not yet available. These technologies are the consequence of the huge increase of computational capacity, actually called High Capacity Computing, which has derived in a number of capabilities such as much powerful treatment of Big Data and faster searching capabilities. This, shall allow solution providers to engage the design of a part or any concept with the applying rules. Another important step forward is that the integration of the validation of the structural models by the Classification Societies shall be done by using cloud computing or with direct connection with cloud applications. This will result in a faster and more reliable design. Monitored full-scale performance data should be analysed in the future in order to improve the performance conducted at the design and manufacturing stages. Performance evaluations should be made, employing developed monitoring and performance analysis methods, so full-scale performance can be evaluated with a high degree of confidence, and its results can be effectively utilized in the ship design stage. CAD simulation tools and Artificial Intelligence for user guidance, Big Data using Artificial Intelligence to help ship designer for optimizing the 3D model, so it is easy to predict that this is the future. There are many advantages of using CAD in shipbuilding: ease of design with the Design Rules embedded, speed of design, use and reuse of information, etc. It is expected that in the future CAD tools will evolve further and allow greater information management through these new improvements, for instance, using Artificial Intelligence, as described in this article. In general, CAD Systems provide tangible benefits while the process is optimized, reducing design cycle and production, and therefore costs. As a summary, there are several scenarios of improvements, as the Design Rules explained in this paper, for the next years. Some of these improvements may seem unrealistic in the short term, but reality often exceeds expectations in any field, and probably more in technology.

1. Introduction

Design Rules are a very broad, generalist and clearly ambiguous concept that can be applied in many fields. Within the same field of knowledge, different concepts can be called Design Rules. It could be also understood the Design Rules, such as the set of rules and impositions that must be followed to correctly design a product. According to this interpretation and within scope of shipbuilding, it could be referred to the rules in different ways.

If the origin of the rules are analysed, these could be imposed by the rules of the administrations, the rules of the classification societies or the constructive norms of the shipyard or the requirements of the final product that may be imposed or required by the final owner of the vessel.

But it could be also the design rules though as all the knowledge available in the design offices, by the designers and engineers that encompasses knowing how to make a boat or what is best for the design of the different parts of the ship. This also includes the adaptation of the designs to the peculiarities of the installation where the product has to be manufactured. Over time, the office and the shipyard, or its workers, have accumulated a lot of experience about the best way to do certain constructions or processes and that experience is materialized as Design Rules aimed at making a design, construction or process more optimal or efficient. This "best practices" area also related to the "on-the-field" experience acquired by the same workers. We'll describe later on how these "knowledge" can be properly levered by using latest, not yet "new", technologies currently available. These rules can also be understood as the set of best practices or guidelines for design. In addition, the set of best practices is applicable to both to the design of the product, as well as to the methodology and means used for design and construction.

But apart from that set of Design Rules, there may be another set of rules that are intrinsic to the designs, and that allow to make an optimal design. These rules are based on the evaluation of the results made by naval designers and shipbuilders. Until now, the evaluation of the results was done in practice, by the naval architects themselves. The attempts to make an evaluation in a systematic way have been based on the standardization of the designs as proposed in the final report about 'World Class Material Standards & Parametric Design Rules', *NSRP (2004)*. However, it is conceivable that the emergence of new technologies of massive data processing, known as Big Data will allow it to be possible to evaluate many more design alternatives and more quickly and the question is how that can be made possible. In addition, for those Design Rules that are linked to the standards, it will be possible to evaluate their compliance during the design stage or after the design is completed. However, it is important not to forget that, as all the systems engineering manuals indicate, the evaluation of the Design Rules has greater value if it is done during the design stages than if it is done when the product is already under construction.

At this point it is possible to ask the following questions:

- How can Big Data technologies help to improve the evaluation of Design Rules?
- How can they help to improve the own rules and how can these technologies find out which rules of design must be applied, if they have been applied correctly, or if the rule itself has to be improved?
- How could be possible to extract new rules and guidelines based on the analysis of the designs made by the naval architects?

In this article, there is the intention to analyse what are the different technologies that can be compromised for it and determine if it is possible to incorporate them and how to do it when this is possible.

2. Knowledge Source

It is clear to mention there is a huge volume of information, some facts in the following Fig.1, 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".

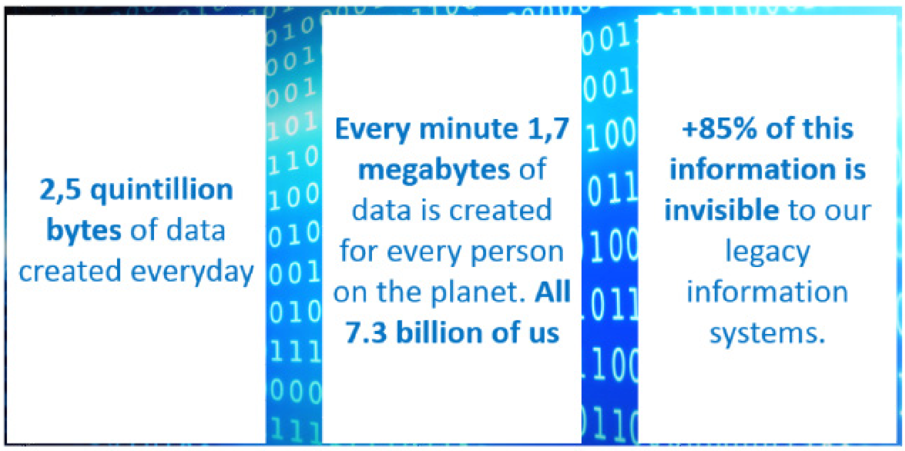

Fig.1: Some facts as regards data creation worldwide

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 has brought key new capabilities that, jointly with pure data management, have carried us to a much powerful capacity to manage that information, as shown in Fig.2.

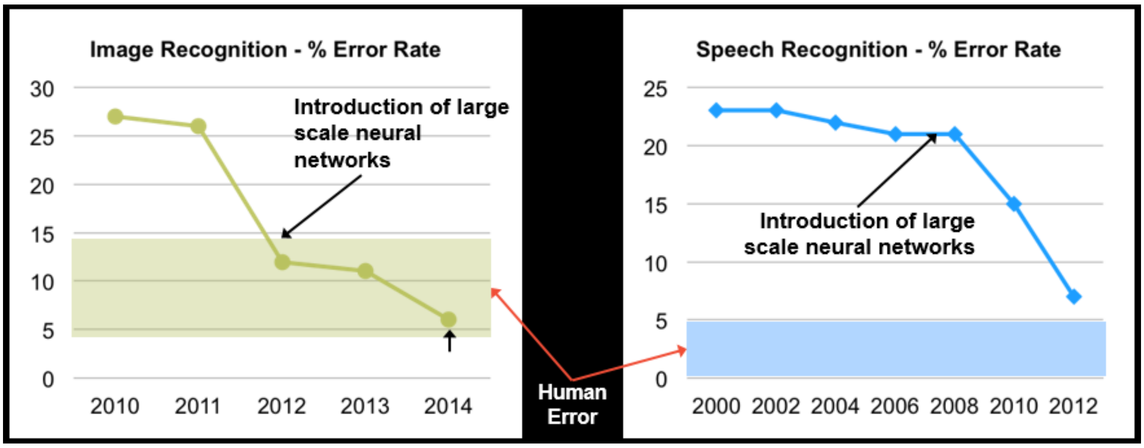

Fig.2: Evolution in Computing Capacity

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 above image 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.

By looking at the image above it is revealed clearly see two branches of Cognitive Computing, lets study how they apply to Naval Knowledge.

2.1. Analytics

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 (almost) 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 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 to minimize impact of those actions to be done.

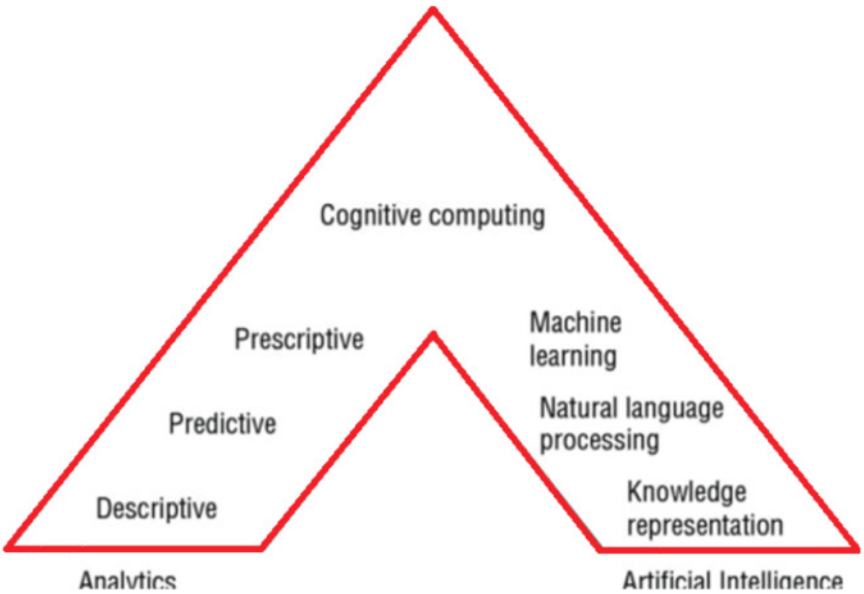

Fig.3: Cognitive Systems Components, *Hurwitz et al. (2015)*

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 article it will be exposed the meeting of placing this prescriptive capability at the top of the angle of the diagram shown in Fig.3, thus highlighting the close connection with the Cognitive branch in that diagram.

2.2. Artificial Intelligence

Similarly to Analytics, a number of concept are included within the *Artificial Intelligence* (IA) and very often confused. However it goes, IA is bringing a dramatic change in the way the information could be managed, related to vessels and shipyards.

There are multiple sources of information in the naval industry that provide information that is not actually structured data that can be analysed in the way it has been described before in this article. Best practices and guidelines like '*Offshore concrete structures', DNVGL (2018)*, where a huge list of guidelines and recommendations are described mostly in periphrastic way: "A document made by the Manufacturer of cement which contains the results of all the required tests and which certifies that the tests have been carried out by the Manufacturer on samples taken from the delivered cement themselves."

Guidelines and recommendations apply to different stages and areas within the vessel construction (e.g. safety, design principles, calculation, testing, reinforcement …).

First contact with AI would be in the text interpretation of content using Natural Language Processing (NLP) to that an AI system is able to understand the context describe in every piece of text so that it can distinguish whether a piece of text (a pill of information) is intended to deal with either safety, calculation and so for. This is what is called the "conversation intent". Furthermore, AI capabilities of NLP will also facilitate de association of this intent with a number of entities that keep linked to a particular intent. All these intents and entities are identified, linked and stored for a further treatment that we'll explain later in this article.

AI capabilities take us much further than pure text interpretation: AI provides text analysis, contextual analysis and semantic analysis. All these AI capabilities will allow vessel and shipyard designers to structure information in a way it could be exploited it in an intelligent manner thus leading to the concept of "Knowledge Representation". Using AI algorithms vessel designers and operators would be able to read multiple volumes of information while structuring it in a way that can be later explored. It has nowadays become very usual in other industries the usage of these capabilities when solving problems, finding best options that suit a design, providing advice based on previous experience and providing suggestion for later actions so the error could be minimized that might optionally occur.

All these capabilities have led to a highly emerging demand of intelligent systems, using AI Algorithms, evolving to next level of Knowledge Management concept called Cognitive Knowledge Management. In this context of Naval Engineering we're mostly focused on the automated and intelligent ingestion of huge volumes of information (unstructured data) than can be explored (as described before) and provided to engineers, manufacturers and operators with appropriate information at the right time in the place they need it.

Finally, AI capabilities evolve as time and interaction with users moves on; AI algorithms based on probabilistic algorithms behind the scenes will continuously update their probabilistic rules based on the interaction the feedback and continuous content provided by users and experts. This is understood as "machine learning" since intelligent systems, somehow apply the experience by increasing the confidence rate in their responses, reflecting the capability of learning.

This point leads to one of the key topics that need to be tackled when dealing with any AI solution, in this case for naval design and construction. This topic is related to the need of these systems to be trained so that algorithms that support understanding and reasoning can be adapted to knowledge demand. AI training and implementation methodology fits out of the scope of context of this document.

There is a reason for this model to place Prescriptive Analytics at the top of this pyramidal schema. By joining both pure data analytics capabilities together with IA exploring capabilities, both vessel constructors and operators will benefit for the union of both two worlds. This means either during the design process, construction or operation, engineers, technicians, constructors can have much easier access to multiple resources by joining together both data and experience, meaning knowledge leverage, thus leading to much more efficient and effective designs and processes.

As a complementary tool for better vessel design and construction is the use of Decision Rules. Vessel construction and operation is highly conducted by extensive sets of rules, some of them already tabulated and some others with multiple dependences to a number of variables and parameters. This is the perfect context for the usage of Operational Decision Rules Systems. These kind of systems provide designers with “natural ways” of defining rules thus avoiding low level coding effort that can be easily modified and updated.

AI can also benefit from using Decision Management Rules Systems by interacting with them always that the AI system is trained to request the collaboration of Decision Management Rules when appropriate thus providing an additional level of intelligence.

All in all, currently, only leading solution designers and developers are already working together with technological companies to come together with much powerful solutions by combining deep shipyard design, construction and operation experience together with most leading technologies, including Advanced Analytics and Artificial Intelligence. However, it is expected that incorporation of these Knowledge Capabilities will progressively and increasingly incorporated to current existing solutions for shipyard and vessel construction in benefit of all the naval sector, in terms of quality, performance, safety and many more advantages to come.

3. Information Lifecycle Management Knowledge Lifecycle Management

The new Knowledge Capabilities described above lead us to real transformation approach for both designers and vessel constructors. So far, and given the extreme volume of rules, regulations, guidelines,… design and construction activities have been continuously ballasted by the need to “manage information” in a proper way; said in a different way, Information Lifecycle Management has been conducting the speed and efficiency of both design and construction.

By incorporating all these Analytical and Cognitive capabilities to both Design and Construction activities, this Information Lifecycle Management has actually evolved to a flow of Knowledge, either it comes from structured data or unstructured data, across both design and construction processes, not meaning anymore a ballast but, much rather an accelerator or catalyser of these corresponding processes helping them actually become much more effective and efficient.

As a consequence of this evolved approach, both designers and construction can focus their efforts of those activities where their personal skills and abilities revert in a much robust product, the vessel. In order to do that in an effective manner, both designers and constructors should clearly identify the activities where the usage of knowledge represent a key factor in their performance.

It is also important to highlight that this Knowledge Lifecycle Management is not only limited to initial stages in the design or construction. Much on the opposite way, Knowledge Lifecycle Management extends on a continuous bases along design and construction activities. Actions like sharing past experiences, providing design advice, notifying about potential alerts… Where not feasible in the past. By adding both Analytical, Decision Rules and AI capabilities together, Cognitive Solutions, to expert knowledge and expertise represent a clear change of paradigm between Information Lifecycle Management and Knowledge Lifecycle Management.

These new paradigm gest seriously impacted and improved by the incorporation of Natural Language Interaction between designers as this interaction can already been performed by using human language, with their different variability depending of geographical locations, languages, etc.

Al this capabilities can even be enhanced by adding commentary capabilities based on vision management. Images can also be managed by IA systems so that patterns are recognized so that specific design components can be recognized, but not only recognized; structure components can be checked using in order to find deficiencies, problems, failures, etc. This can also be supported by latest technologies like drones and high quality cameras (including thermal, 3D, high resolution cameras) and Internet of Things (IoT). All these technologies and capabilities fit out of scope of the current document.

4. The Issue in Shipbuilding

Shipbuilding market conditions have suffered a significant evolution over recent years. Ship delivery times have become even shorter, and thus demanding a similar reduction in the design and engineering cycles. On the other side there has been an important reduction in the work force capacity of the shipyards, obliging them to subcontract significant parts of the design work to users with less skills.

The practice of Design Rules is gaining momentum in the shipbuilding industry as its numerous advantages become evident. Shipyards can increase their competitiveness by reducing design time, improving ship design quality and co-operating in the most efficient way with other companies, which need not be shipyards or engineering subcontractors, but also classification societies, equipment suppliers, regulatory bodies and even ship owners. Shipyards, large, medium or small, merchant or naval, want to have Computer Aided Design (CAD) applications with the capabilities of Rules Based Design.

The U.S. National Shipbuilding Research Program, *NSRP (2004)*, promoted and funded a project entitled World Class Material Standards and Parametric Design Rules. The main objective of the project was to develop and implement a Rule-Based methodology for ship design and material selection. The motivation of the project was to enable associated U.S. shipyards to respond quickly to customer inquiries and develop contract design packages, including cost estimates, which in addition to quick response have minimum risk to the yard in terms of price and schedule. As it was exactly described in the project web page, *NSRP (2004),* the goal was a 33% reduction in cost and cycle time for pre-production processes during the contract, transition and detail design phases.

The Rule-Based methodology, Common Item Database, standards and parametric design tools are applicable to the U.S. shipbuilding industry at large. Among the several tasks covered by this project was the development of a technical approach for the early stage and a parametric ship design tool, which basically consisted of elaborating an integration between several different software devoted to the different aspects of the design.

Another task of the same project was to develop metrics and rules for the Entire-Ship design. As anyone can imagine the complexity was of such magnitude that it had to be focused on three generic ship types for a medium sized shipyard: container ship, product/crude tanker and Ro-Ro ship. The catalogue of captured rules had over 500 rules. This gives an idea of the difficulty of managing this into a single tool. Even more difficult when considering the possible changes in regulations. The task number six of that project was to develop zone Design Rules and material templates for each ship zone, to define generic interim products and to define functional volume design methodology and processes. The conclusion of the project made clear the need and the interest to continue advancing in the aspects related to facilitate the application of Design Rules to the projects. But the difficulty of the advance is so relevant that no clear advances have been made or applied in real cases.

Depending on the object in question the rules to be applied will have a different treatment. Since the application spectrum is so broad, it is necessary to make a detailed analysis and propose solutions to very specific sets of elements. When searching for one or several solutions, several criteria can be considered: strictly conform to the design criteria, comply with administrative rules, and reduce design time as much as possible. It is also necessary to keep in mind that some of the criteria may conflict with one another. In such a case, it is necessary to choose priorities carefully, bearing in mind that certain rules are binding.

In general, the criterion of reducing cost is a correct choice. However, it may be the case that time-saving estimates are not accurate. For example, incorporating tools to control the application of Design Rules will make the use of design tools, ultimately the CAD, more costly in terms of performance of the application, but on the other hand it will result in a design that hopefully does not need modifications. One could also allow the use of unrestricted design tools and incorporate validation tools for Design Rules later on. This would make depending on the training and knowledge of the rules that have the designers, the modifications of the design, were more or less ample. How could be estimated what is most beneficial? Certainly it is very difficult to make a prediction and the result will depend very closely on the type of vessel being projected.

Probably, the most suitable approach is to use an intermediate solution. First, to embed design methods that properly conduct the project by adjusting the use of specific materials or standard elements, equipment, fittings, etc. Second, to provide tools that help to know and to apply the Design Rules established by the different stakeholders. Finally to provide some method or tools to validate the rules in order to assure that the design conforms to them fits the rules.

4.1. Shipbuilding Design

It is completely out of the question whether to use software to make the design model. The complexity of marine designs makes it necessary to use different software applications for the realization of the designs, obtaining the relevant calculations and validating them. It is also evident that the greater integration between different software, the greater the time savings in project development, basically due to the use of the different models in the different applications.

Each stage of the design project will be subject to its own rules as the variety of the same requires to make a specific use of software applications to have the design adjusted to the requirements. This assortment of functionalities and therefore of rules makes it impossible to combine in a single source all the rules, *Muñoz et al. (2017)*. To make matters worse, the rules are constantly changing. This is due to the fact that the rules have different objectives and with each project it may be necessary to readjust them.

Hadjina et al. (2015) propose a methodology based on the Quality Function Deployment (QFD) to take into account during the designs of the naval projects, the experiences obtained with the same by the ship owners and crew. The authors take into account the percentage of remarks obtained after delivery the product to prioritize the set of subjective customer requirements into a set of system level requirements for a future system conceptual design. As a result, they stablish a set of guidelines, among them highlights the improvement of the ship Design Rules and procedures and finally they suggest the necessity of elaborating a document of guidelines. In their work it is very remarkable that the 26.4% of remarks, second position after defects in assembly, are regarding noncompliance to the good shipbuilding and seamen practice in terms of working and living on board a ship. And in the fourth level with a 9.3% are the Remarks regarding the accessibility and obstruction during the movement of the crew through the ship. These two groups of remarks could have been reduced if during the design of model in the different applications it had been possible to validate or to consult the Design Rules.

So, currently the ship design process uses CAD as a tool and the application of the Design Rules relies in the designers and engineers. It is therefore necessary to incorporate new methods and tools to facilitate this application.

4.2. Design Stages

Focusing in the different stages of the project can give a good classification of the Design Rules and allow to identify which of the Design Rules deserves to be embed into the CAD or which is the best approach to address this issue, *Muñoz et al. (2017)*.

In the conceptual design, the Design Rules to be considered are related with naval architecture calculations. The evaluation of the stability criteria can be considered as Design Rules. These rules are established by international agreements and published by the International Maritime Organization (IMO). Having the evaluation of the criteria integrated in the CAD shall have a positive impact in terms of cost savings. Otherwise it will be necessary to export the forms into separate format and to make some rework in the specialized software. Most of the specialized software covers the majority of them, but sometimes it is necessary to add specific calculations made with parametric formula. Not all the software are enabled to address it.

Initial and basic design also requires the validation of the structural design from the point of view of the classification societies. For this purpose, models have to be exported into the specific format for the structural calculation. There is an additional step that adds complexity to this process and it is that the classification societies normally wants to review the models by their own means.

General arrangement in the basic design stage also requires the fulfilment of specific Design Rules, as those related with the compartmentation, spaces, volumes, etc. During detail design stage the project is expected to be finished from the point of view of the design. However, it is when more in depth observation of the rules has to be done.

Definition of the specific structural elements have to fits the classification rules, but also a high amount of equipment have to be located in the ship. The location is in many cases subject to determined rules, for dismounting, for functionality or even for aesthetic reasons. The amount of equipment means that following the Design Rules expends a large amount of time and hence, it is where the most of time savings can be obtained. So, it is in the detail stage when the validation is more necessary.

Some software vendors should provide tools and methodologies for controlling the project model from the point of view of the Design Rules and for facilitating the transfer of the model for validation purpose to external and specific applications. The different tools should be adapted in the different stages of the project and also for the different elements of the ship project and the ship design.

However, the number of rules can increase exponentially according to the type of the project, and in some cases, such as naval ships, the amount of rules is so high that it might be impossible to manage all of them, because the application could collapse during the definition of the different elements.

5. Data Treatment

As it was explained, a work methodology was intended to establish with the data that allows to improve the naval designs, the product, and its processes throughout the life cycle. This methodology is based on incorporating all the information, data, available to shipyards and technical offices to build efficient Design Rules and improve existing ones, facilitate the application and verification of existing ones and do it throughout the life cycle.

In the treatment of data, there is a substantial difference with the treatment of Big Data that is done in other areas. Currently, the greatest use and treatment of data is carried out in the fields of Financial Services, Outdoor Media, Retail, Tourism, Transport, etc., which are where there is a massive incorporation of data. In those cases, the objective is to know who, when, why and how is using data from the network all over the world. While in the matter that concerns us for this paper the objective is to get data to obtain a good design or a better process. In comparison with these fields, what is obtained from shipbuilding Design Rules and their application, is tiny, but it does not stop being necessary to carry out the correct treatment of them.

Although in the paper it is writing about using Big Data methodologies to be used in the treatment of Design Rules, as described above, it should not been forgotten that under the concept of Big Data, different technologies are included that make possible the effective and efficient use of the large volumes of data that need to be managed. For all of this it is necessary to take into account the following aspects:

- Variety of typology of Design Rules:
  - Design Rules, understood as normative
  - Design Rules understood as best practices, i.e. the adaptation of the rule to optimize the design and construction processes
  - Design Rules understood as design optimization to improve design efficiency
- Variety in the origin of the data
- Algorithms of data processing for its application in the process of design or production
- Variety in the fields of application of the Design Rules:
  - Design adjusted to requirements and standards

- Product efficiency
- Improvement of production processes

The first stage is the collection of the data. At least the following phases or stages can be considered and they are different depending on the type of data and its final destination:

- Compilation or capture
- Sanitization
- Integrity
- Governance

5.1. Capture and/or Compilation

The compilation of data is intimated related with the origin. In the naval field, the different offices and shipyards have their own working methods and their Design Rules. It can be said that this set forms a static database that must have an initial population. For processes to be effective, this must be centralized and have an efficient data structure. These data structures must be prepared to be applied in the design processes and therefore integrated in the CAD, this is what is known as embedded rules in the CAD, *Muñoz et al. (2017)*. For this the data must have an appropriated structure to the target. As an example, *Albers (2005)* propose the use of the knowledge-based engineering and the systematic storage of the Design Rules in an agnostic format independent of the CAD system, with six descriptors:

- A brief verbal description of the rule
- Eventually a picture
- A mathematical equation as a condition that refers to the part's geometry
- A unique key that identifies the rule and it scope
- Instructions what to do if the condition is true
- Instructions what to do if the condition is false

Description --	Approval Domain ----
Clocks are to be fitted at a height of 1850mm above the steel deck to the centre of the clock.	Outfit
"Clear deck height - the minimum Clear Deck Height (CDH) is: 2200 mm for main passageway or compartments and spaces where personnel are sometimes required to wear a helmet 2100 mm for compartments and spaces where personnel are not usually required to wear a helmet 2100 mm for cabins and infrequently accessed compartments, e.g. storerooms, workshops"	Outfit
Where URN signature requirements do not impose pipe bends greater than 3 x diameter of pipe, a 3 x Dia pulled bend will be the preferred option. Where spatial constraints do not permit 3 x Dia and manufacturing capability exisits an alternative 2 x Dia pulled bend may be used, but only with approval from responsible stage 1 systems owner.	Auxiliary Systems
This rule shoud be applied in conjunction with rule 472. Bends on pipes should be selected in the following order:- 1st choice - 3D bends with clamping 2nd choice - 3D bends without clamping 3rd choice - 2D bends with clamping (more cost effective than a LR elbow)	

Fig.4: Example of Owner´s Design Rules

This proposal can be very suitable to control design variables and results. However, the structure of other types of Design Rules may have to be adapted to the type of rules, such as regulations or requirements. See for example the set of rules to be applied for the accommodation of a naval ship or the structural rules to apply for the physical limitations of the workshop, as shown in Fig.4. These are currently managed in separate and individual documents as worksheets in Excel® or similar.

As regards the rules and standards regulated by the administrations or classification societies. Although many of them are very similar, if not equal, each organism organizes them in a different way. Therefore, there is no single data source or it is not structured in a logical way that allows computerized systems to processing them by any means. Furthermore, there is not any standard or unique structure of data that facilitates the treatment. So, the incorporation of all these rules in a single and centralized system of Big Data technologies is a great challenge for them.

In relation to the data of the design processes, it is referring here to processes and stages that a user executes during the design of the product. Repetitive processes, which could be detected and executed automatically and with automatic application of the limitations imposed by the rules. For this it is necessary to have a logical format that describes any of the processes and in a format that can be interpreted by a computer system. This type of language always needs an adequate interpreter. An example of this is the *Jason®* language. A design tool can record all what is done and then interpreted to do the same or to anticipate the user´s action and propose specific actions or do them by themselves using an automated or on demand system, Fig.5.


```
{"type": "HEADER","value": {"build": "2018 beta","host":
"WS12857","module": "fpipe","revision": 280945,"timestamp":
"2017-11-24T10:14:22+0100","version": "v80R1.0","x86_64":
true,"customer": "SMAR"}}
,{"type": "DLGMESSAGE","value": {"timestamp":
"2017-11-24T10:14:32+0100","trace": "Forms file not found:
\nC:/Foran/Ships/V810/TST8fsurf.fsf"}}
,{"type": "COMMAND_START","value": {"name":
"OfsScnFileReaderCmd","startTime": "2017-11-24T10:16:40+0100"}}
```


Fig.5: Jason script of CAD commands execution

Finally, there is the set of data that are the result of the evaluation of design variables and whose objective is the improvement of the design algorithms, i.e., the Design Rules to improve the efficiency of the project or improve the design itself. These data must be obtained from the product in its exploitation and operation stage. This engages with the IoT world and the capture and treatment of data to make decisions that improve the operation of the ships and beyond of this, the own design of future vessels.

5.2. Sanity

According to *Reguero (2017)*, "to obtain bright insights, we must feed the algorithms with data that meet minimum quality". Data cleansing, data cleaning or data scrubbing is the process of detecting and correct, or eliminate, incorrect or corrupt records of a set of data, table or database; identify incomplete, incorrect parts, inaccurate or irrelevant and replace, modify or eliminate erroneous data. The process of data cleansing can be done interactively, with Data Wrangling, sometimes referred to as Data Munging, tools or in batch, through the execution of adequate scripts. Cleaning can be done manually or by software. Manually means using a tool that allows the classification and cleaning of the vast amount of data. Excel is an excellent tool for that. However, there are also a wide variety of tools specialized in data cleaning such as OpenRefine®, Trifacta Wrangler® and DataCleaner®, which are simple, fast and very efficient.

To better understand what data cleansing consists of, suffice it to say that the usual tasks are:

- Discard fields
- Match formats
- Correct spelling mistakes
- Format dates
- Remove duplicate columns
- Delete unusable records

5.3. Integrity

After cleaning, the data set must be consistent with others similar in the system. The inconsistencies detected and eliminated are usually caused by human errors, corruption of data in the transmission and storage processes, or differences in definitions of data for similar entities in different databases. The data must be related each other and with the final objective, in order to be able to correctly infer the scope of application.

The integrity must be by specific applications oriented to the final target. Normally this is done by using specific programming languages that have powerful libraries for statistical algorithms and for processing large structured data files, as *R*® or *Python*®. It is definitely what is known as data discovery. Data discovery consists in the coordinated use of a series of techniques and methodologies to integrate and analyse different data sources. So that it is possible to discover relationships and behaviour patterns in the data sources and that are not perceptible through traditional analytical techniques.

5.4. Governance

Finally, the data must be stored so that they are accessible to the algorithms that will work with them. There are multitudes of databases and there are many criteria that can guide the choice of database. The most traditional and powerful, such as Oracle® or SQLServer®, now appear a new generation of databases oriented to these technologies. They are the databases known as NoSQL, http://nosql-database.org. NoSQL, not only SQL, includes a set of database management systems that differ from the classic relational model, in aspects such as: not only use SQL as query language or that the data does not always have to be stored in tables, normally they do not support JOIN operations, nor completely guarantee Atomicity, Consistency, Isolation and Durability (ACID), and usually they scale well horizontally. Some of them are: Hadoop®, MongoDB®, IBM Informix®, Cassandra®, etc.

All these steps with being necessary, have to be adapted to the concept that it is intending to handle of application and improvement of heterogeneous, embedded and, if possible, automated Design Rules. In this process, it is essential to be clear about the design and construction process and at what stages of this process it is possible to take advantage of a possible treatment of Design Rules with Big Data methodology.

6. Leverage of Knowledge

How *Evans (2018)* explains in his web site, “Knowledge Management is the process of pulling together people, systems and tools so that an enterprise wide structure is in place for efficient and effective decision making”. It is ironic that so many companies have an abundance of knowledge but fail to use it for managing the business. Knowledge is a critical resource that warrants much more attention. If about managing knowledge it is being discussed, then it is necessary to embrace the concepts associated with knowledge management.

Knowledge management is not only an Information Technology (IT) project. Knowledge management is more about understanding the resource and knowing how to leverage it for growing the business. Technology (such as enterprise portals) is often deployed to help leverage knowledge. However, it may be more important to focus on the information itself, knowing how to classify it and analyse it before it is given everyone access to it. In case of the shipbuilding, this approach is essential. “Ultimately, intellectual assets have become more important than any other because only by means of knowledge can companies differentiate their work from their competitors,” *Stewart (2002)*.

In the same way that prototypes can be used to increase the leverage of knowledge, also design based on Design Rules will allow to grow the leverage of knowledge and with it the value chain of the company. At a time when generational changes coincide with disruptive technological changes, it is more than convenient to find ways to maintain the full legacy of knowledge that people have in the company and empower it with new technologies. It is not only about making a design well, but also about making a good design and the application of Design Rules, standards and norms, but also the knowledge and expertise of the companies contribute to that task.

Big Data technologies open opportunities for us to allow all that knowledge not to be lost, but rather to be taken advantage of. In addition, technologies such as artificial intelligence and machine learning can give this increase in value that helps companies survive. The application of these technologies can be found in very different stages of the design process.

In the beginning of the design process, the results of previous designs can be used for preparing the new designs that improve the previous design. Of course, this can be done by direct application of knowledge, but if there were a single source to consult that knowledge, it would be easier and more efficient to do that task. It is increasingly common for companies to incorporate “lessons learnt” databases into their process, but in practice the introduction of this information is so tedious, that it is left to the end as the last step that nobody pays attention to what really deserves. It is about fulfilling an obligation and when someone intends to consult it, the information obtained is a repetition of data without any value. This could be resolved if there was an automated way to feed that information. For this reason, it is necessary to structure the data that could be required to recover or maintain for the future. Carrying out this work first passes through the selection of those variables whose results are data that assess value in the future for decision making.

Some proposals have been done as regards the previous, such the interesting investigation of *Sjöman et al. (2017)*, where they describe a theoretical framework for an evolutionary repository for capturing information and knowledge from real industry projects, and sharing this output for both researchers and practitioners in engineering design.

Once it has been defined what it is required to obtain, it is necessary to have the appropriate algorithms to correctly relate the collected data and their relationship with the design variables to determine the influence of one on the other. It is about not only presenting the information but also crossing as much as possible so that all the possible relationships between one and the other can be found. Having powerful algorithms allows to explore and analyse everything that human beings would take much longer.

This is where machine learning starts playing its role. The incorporation of learning algorithms and learning models through what is known as Support Vector Machine (SVM). SVMs are supervised learning models with associated learning algorithms that analyse data used for classification and regression analysis. Given a set of training examples, each marked as belonging to one or the other of two categories, an SVM training algorithm builds a model that assigns new examples to one category or the other, making it a non-probabilistic binary linear classifier, although methods such as *Platt (2000)* scaling exist to use SVM in a probabilistic classification setting. An SVM model is a representation of the examples as points in space, mapped so that the examples of the separate categories are divided by a clear gap that is as wide as possible. New examples are then mapped into that same space and predicted to belong to a category based on which side of the gap they fall, *Cortes and Vapnik (1995)*.

Finally, it is necessary to have the appropriate infrastructure to take advantage of all the information collected. In this sense, systems such as Hadoop® provide all the support that may be needed. Hadoop® is an infrastructure technology that allows the storage and processing of large volumes of data, through a storage system and distributed computing, which makes use of: a few servers up to thousands of them, and simple programming models. The Hadoop Ecosystem® is made up of a set of tools that have emerged to facilitate the management and analysis of Hadoop® data. In this way, it is possible to find tools to load and transform data, others for the query of stored data, cluster management, streaming and Machine Learning.

But the entire infrastructure requires that all the knowledge to which it is making continuous reference is implemented. In this sense, large companies such as IBM makes available to this objective, systems such as Watson IoT® , *IBM (2018)*, which deploys a broad set of solutions to give intelligence to all this data collection.

7. Conclusions

The Design Rules in any of the described form are part of the knowledge of the shipbuilding companies and it is appropriated to have them accessible in all the stages of the design and building process. The heterogeneity of rules due to their origin or application means that it is not possible to incorporate a single treatment system, but rather to address what provides the most added value to the final product. To take advantage of the knowledge provided by data management and the value they have in the context of Design Rules in shipbuilding, some aspects must be addressed. Depending on the scope wanted to achieve when looking for a solution to the different aspects that are involved in this matter.

It would be necessary to decide on a single data structure and how, unfortunately, that will not happen will require an introduction of the data manually. The question here is whether it would be possible to develop a technology capable of interpreting all those rules and adapting them to an adequate data structure to facilitate the search and application. Does it make sense? Is someone willing to pay for that added value?

The current existing tools are oriented to the processing of the data in order to know commercial behaviour of the consumers or the use and behaviour of objects in order to elaborate maintenance or use processes. The case of the Design Rules is quite different due to several reasons:

- There is not a high volume of data
- This volume of data is not renewed with certain frequency
- The ultimate purpose of these data is much more complex than the previous one

Therefore, it is necessary to redefine the processes of data acquisition and processing and as a consequence, also the tools.

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