CONNECTING THE VIRTUAL WORLD TO THE REAL ONE

How do we find logic in the big pool of data? – ICCAS part 2

In SWZ|Maritime's previous issue, the first part of the report on the International Conference on Computer Applications in Shipbuilding (ICCAS) that took place in Genoa in September was presented. This second part reveals more about connecting the real world to the virtual world and how to handle the big pool of data that emerges from measurements in real life. Real life measurements allow machine learning to take place, and with artificial intelligence (AI), this knowledge and the work of an engineer becomes more engaging and accurate. A digital twin of a ship or shipyard can make this happen.

To create a digital twin, information is managed in several layers (see figure 1). Sensors collect a lot of data from the physical ship and its environment. By an integrated network, the data is transported to a "big lake of data". But how can we make logic of this data? Several tools and applications provide different views on the data, from which decisions can be made.

Connecting engineering to the real world

Measurements in the real world provide a deeper knowledge in design and engineering calculations. In the GATERS project, full-scale performance tests are compared to computational fluid dynamics (CFD) calculations, model tests and monitoring data of the operation of a gate rudder (GRS) on different ship types. Also, a comparison to a conventional rudder (CRS) is analysed. The results show differences in the required propellor thrust and, thus, in fuel consumption. CFD and model tests are working in an environment where the flow is steady and calm, this is quite different from a conventional rudder behind a propeller. This might explain some of the differences, but a lot in real life is still a mystery [57].

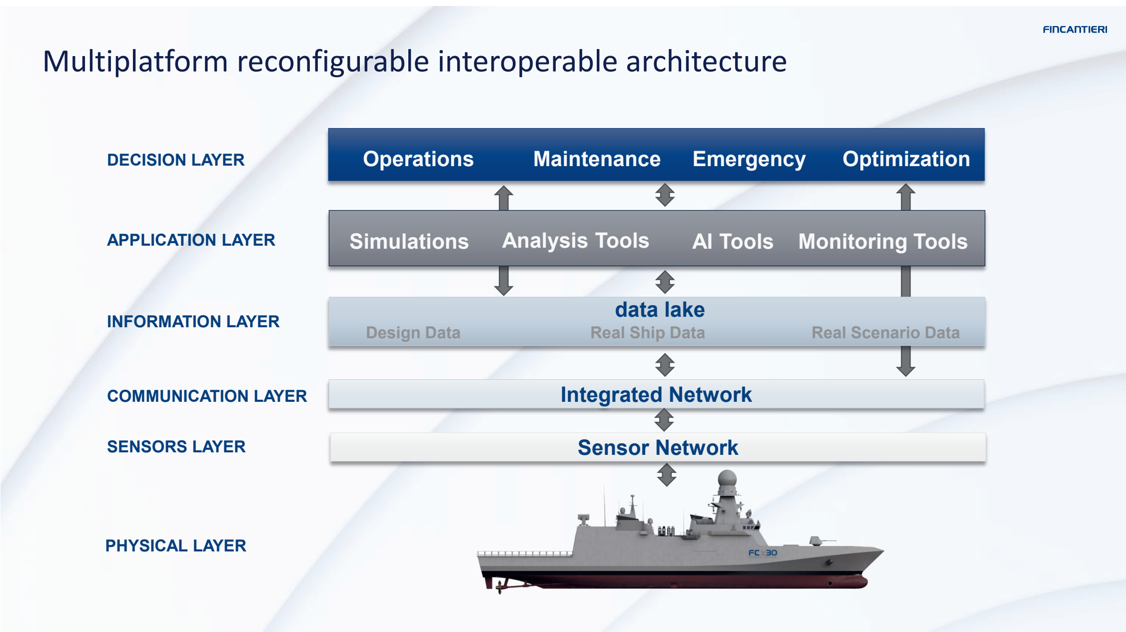

Figure 1. Integration of information and communication in different layers (image Fincantieri).

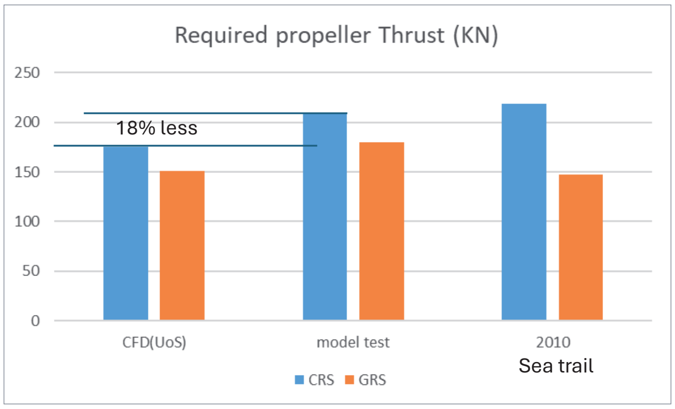

Figure 2. Comparison of CFD, model test and sea trials for a conventional and gate rudder (graph Noriyuki Sasaki, University of Strathclyde [57]).

By connecting finite element method (FEM) analyses with acoustic measurements on board, class societies are able to predict the noise and vibration levels on board and in the environment the ship is in. With this information, insulation plans can be optimised, which can result in additional class notations. With acoustic cameras, the analysis of tonal noise and acoustic privacy in specific situations elevates the study of acoustic comfort to higher levels [33].

Traditionally, ship stability is calculated during the design phase and verified through an inclining test upon delivery. However, a ship's condition changes over time, and intermittent checkups provide insufficient information. Integrating in-service stability measurements within ship operations allows for real-time evaluation of the vessel's vertical centre of gravity (VCG), enhancing conventional stability assessments. By combining data from the onboard loading programme with statistical process control techniques, it becomes possible to diagnose changes in the lightship vertical moment throughout the vessel's lifespan. This enables crews and managers to address weight discrepancies and maintain control over the vertical moment, avoiding penalties while complying with stability regulations. As the number of measurements increases, stability predictions will become more accurate [35]. External factors, such as waves and weather, can introduce bias. However, by digitally monitoring sea conditions, predictions of the future can become even more accurate.

During the preliminary design stage, critical decisions are made regarding design speed, autonomy, and operational conditions. These factors influence the vessel's energy requirements. Traditional methods of estimating design speed and operational time based on experience or intuition often lead to unrealistic scenarios. Therefore, analysing AIS data from existing vessels is proposed to determine activities executed, time spent at sea, in port, operational speed distribution, and encountered weather conditions. This analysis helps naval architects determine more reliable energy requirements and design ships for realistic scenarios. It also assists in convincing shipowners to choose sustainable fuels or batteries by showing sufficient recharge or refuel times when moored.

By digitally monitoring sea conditions, predictions of the future become more accurate

C-Job applied this approach to a roll-on/roll-off ferry and a trailing suction hopper dredger, finding the ferry suitable for battery power and optimising the dredger for reliable operations. From the ferry analysis, it appeared that capacity was not used optimally, which could result in a smaller vessel. This resulted in up to fifteen per cent weight and fuel savings. Customers often think they know how the design of their ship should be. For instance, an owner wants his ship to travel at 20 knots, but the operational profile analysis showed that the ship mostly sails at 7 knots. Design choices can be more data driven and this lets designers help their customers in making the right decisions at an early stage [41].

Automatic monitoring during operation

Fincantieri presented a solution for gathering information from the

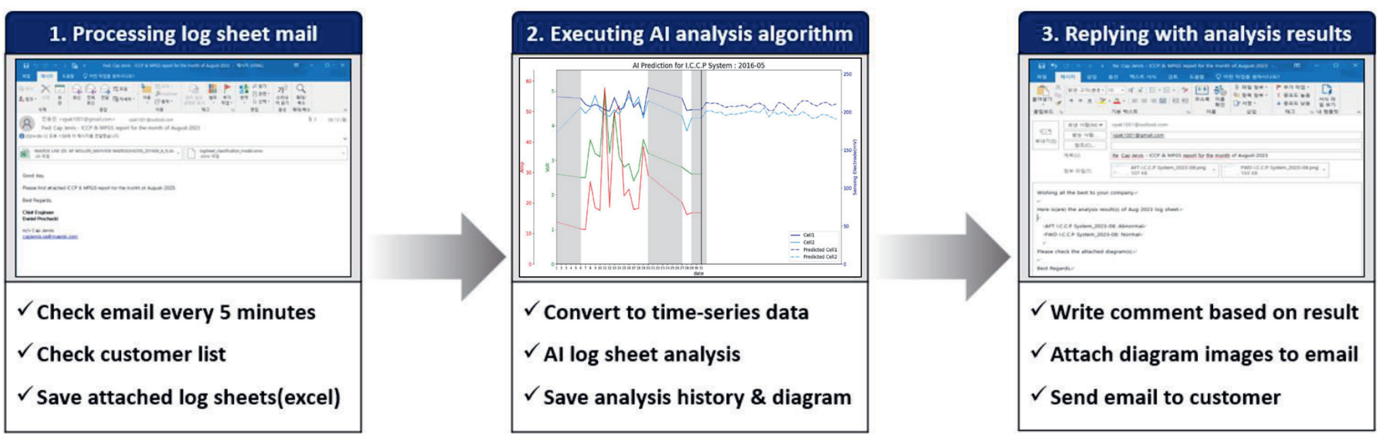

Figure 3. Automation of a lifecycle management process (image Research Institute of Medium & Small Shipbuilding (RIMS) [10]).

surroundings to ensure sufficient situational awareness for autonomous vessels. The solution includes a customisable interface that consolidates all collected data for a single operator. During a ship's operation, the Object Detection module within the Situational Awareness System provides clear and accurate information about incoming vessels and floating objects, with a focus on the operator's needs [14].
For propulsion and power generation engines, predictive maintenance systems use sensors and connected devices to continuously collect crucial operational data. Integrating this real-time information with digital data allows for the early identification of potential issues, reducing the risk of catastrophic incidents and enhancing safety at sea. This approach minimises downtime, extends the lifespan of critical components, and improves fuel savings and overall cost-effectiveness. Additionally, digital technologies facilitate the adoption of fuel cell systems as a zero-emission alternative to traditional diesel generators [36].
Another example of monitoring data is the use of sensors on the ship's cathodic protection system. The big pool of log data from this sensor is hard to analyse, so an AI-based algorithm has been developed that transforms the data into graphical representatives and sends an email to the shipowner when action is needed [10].
Another example is the collection of data on the biofouling status of the hull and propellor of Holland-class Ocean-going Patrol Vessels. Combined with AI and first-principle techniques, a set of real-time fault detection and short-term biofouling forecasting tools have been developed that can be used to supplement a maintenance strategy [22].

Monitoring on the production site

Often we see that the digital chain is broken at the shop floor, despite significant investments in automated equipment like robotics and intelligent logistic handling equipment. In this case, “broken” means that the information provided to the shop floor is often still in the traditional deliverables like spreadsheets and drawings. Companies that successfully maintain a digital link between design and production tools have seen substantial improvements. Three key aspects contribute to this success:

- Reliability of data to be entered into the fabrication process.
- Confidence of information provided and the impact on the requested deliverables.
- View of the complete supply chain.

These factors influence shop floor operations by reducing the time spent on checks, enhancing quality, and decreasing demand for certain deliverables [38].
Another production facility research project was presented that provides suggestions to workers to improve their posture and thereby their health and safety. With the use of Lidar sensors, three-dimensional recognition and estimation of shipyard workers’ postures have been examined [28].

Deeper analyses in the design phase

Where computer capacity and speed are developing, more and more complex and advanced calculations and simulations can be made. These provide engineers with a deeper understanding of the ship and its possibilities. A quick overview is presented in this paragraph.

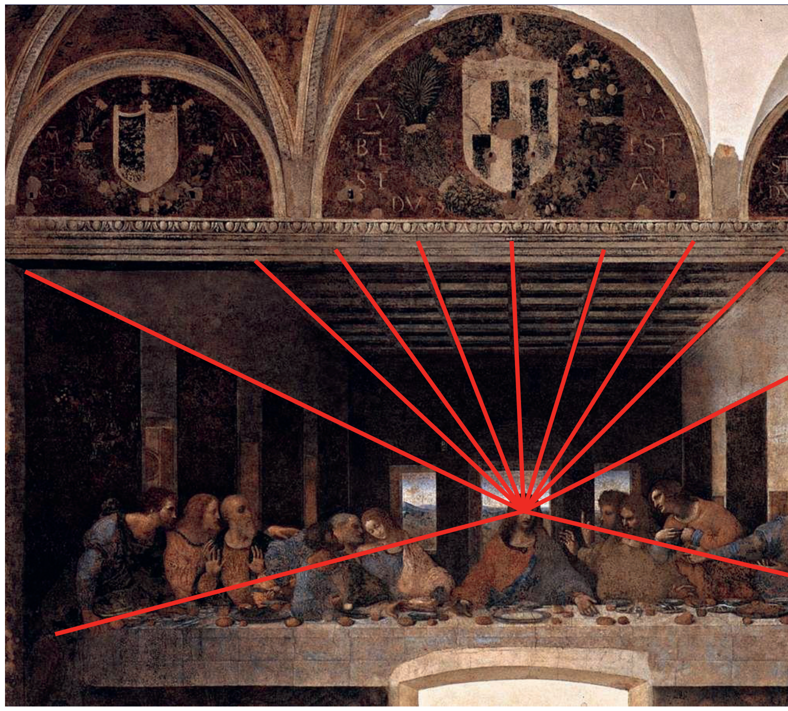

Figure 4. DaVinci painting with perspective (image Siemens [40]).

Particularly for large structures like ships, a lot of structural analysis is required from the design stage through to construction. Final element calculations can be more precise with the use of smart calculations. Traditionally, engineers model the entire ship and iteratively perform localised fine meshing of critical areas. As regulations are strengthened and the size of the ship increases, the number of these fine meshing areas are increasing, requiring more and more working time from engineers. To solve these difficulties, several authors of the conference proposed different options. The first is a mesh copy function, which copies a user selected finite element region to another region. This is useful for ship modelling that requires repeated fine meshing in similar regions and for analysis that requires repeated changes to modelling parameters in the same region [27]. Another option is to simplify the analysis by idealising a structure as a beam or a frame, which is a collection of beams. This grillage structural analysis is less accurate compared to finite element analysis (FEA), but is very useful for enabling quick model creation and analysis [45].

> With integration of design software, the design spiral has now become a balancing motion

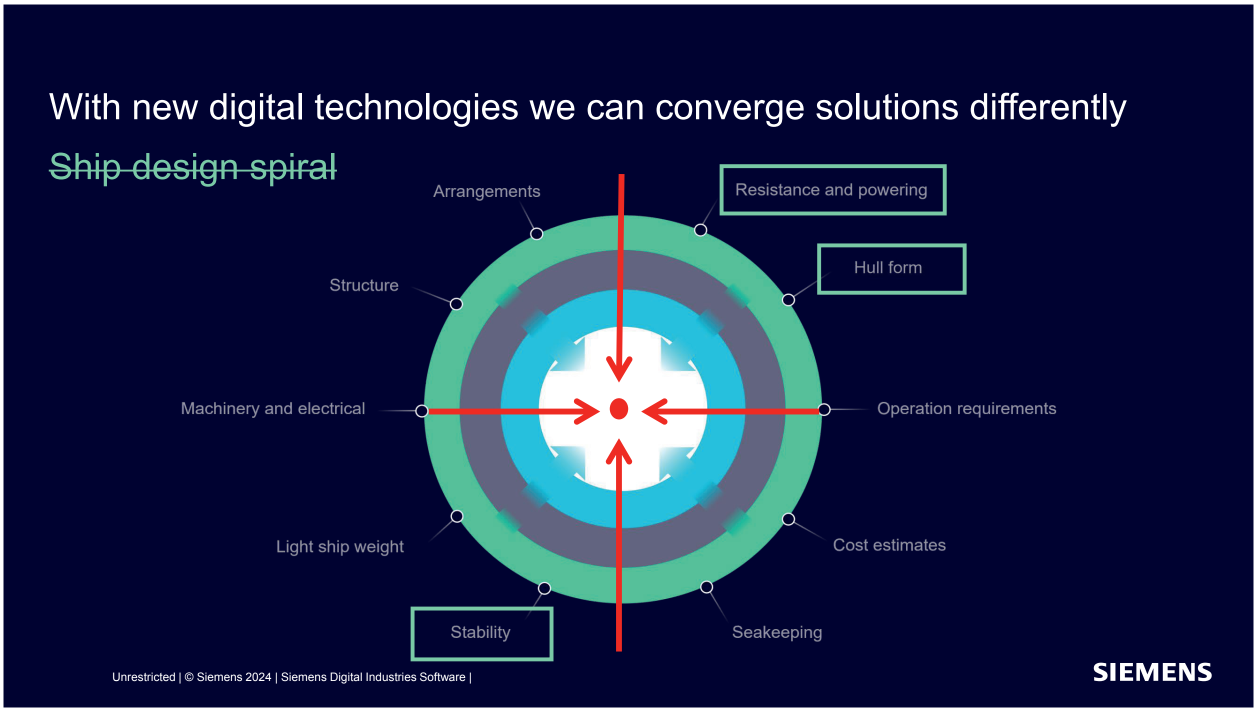

Figure 5. Perspectives in the design balance (image Siemens [40]).

The pipe routing in the detailed design phase can also be optimised. Automatic routing of pipes is now becoming more accurate in curved structures [18]. Simulation of pipe installation based on a path planning algorithm can prevent collisions, evaluates assembly feasibility at the design stage and assists planning production with more accurate assembly procedures [49].

Probabilistic methods for verifying the stability of dry cargo and passenger ships has improved the accuracy of damaged stability calculations, but increased computational demands. Generation of extensive damage scenarios is especially challenging when ship compartments vary in shape and alignment. An algorithm developed by the Korean Maritime and Ocean University automatically generates damage scenarios for compartments with arbitrary shapes. It determines the topological relationships between adjacent compartments using geometric data and considers both traditional and complex connectivity directions [19].

Navantia is developing a tool to enhance the design process of ship propulsion systems. The tool generates a list of all the possible configurations of the propulsion system. The developed code is applied as a filter to each configuration. This filtering is based on knowledge and criteria of engineers together with the requirements of the project (for example, diesel engine average load must be higher than forty per cent). By relying on data-driven approaches and standardised criteria, engineers can minimise the impact of personal bias [42].

Dassault Systèmes integrates digital modelling and simulation to optimise wind-assisted ship propulsion (WASP) systems. The process starts in an aerofoil shape optimisation tool, focusing on maximising the lift-to-drag ratio. The optimised aerofoil is then assessed in 3D on a ship's deck via a steady-state Reynolds-averaged Navier-Stokes (RANS) simulation. Following this, the fluid-structure interaction workflow continues with structural analysis. Key components such as the thickness and location of spars and ribs are optimised to handle aerodynamic pressure while minimising mass and stresses. While this approach reduces turnaround times and improves design efficiency, still a lot is uncertain because only the foil is analysed and the operation depends on a lot of factors. The next step would be to analyse the system in relation to the ship and sea state [51].

CFD calculations have been proven to be a powerful tool for the analysis of several complex phenomena. New applications of CFD can be found for the analyses of cryogenic fuels (such as LNG) and tanks integration on board cruise ships [15] or calculation of the launching of ships on a slipway [9]. A very futuristic use of CFD is the examination of hybrid unmanned aerial vehicles (HUAVs) in Australia. These autonomous vehicles are designed to operate in both air and water: free diving into a body of water and breaching to re-achieve flight [37].

From design spiral to balancing perspectives

Some say the design spiral is no longer contemporary, because digital systems evaluate the design aspects not in a step-by-step order. Still, the evaluation of design aspects is what ship design is about. With integration of design software, the spiralling has now become a balancing motion. Every aspect is important and just like the integration of systems, proposed ideas and design concepts are additional to each other and not competitive. Several interesting ideas on this topic were presented.

Siemens presented an interesting view of "perspectives" and compares this to the Da Vinci painting "The last supper". All lines in the

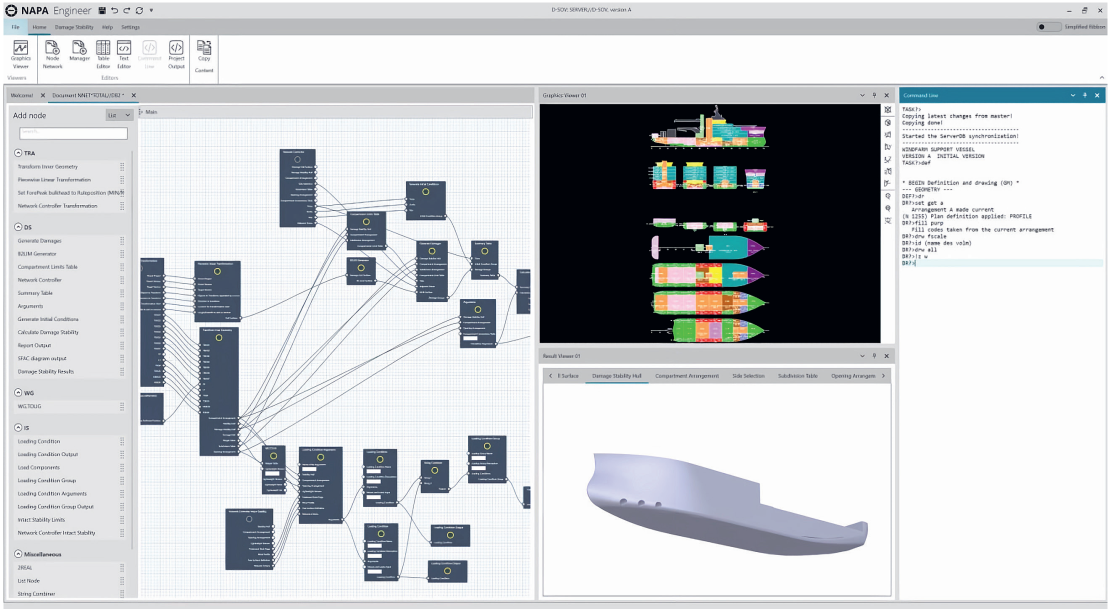

Figure 6. NAPA's network of nodes (image NAPA [56]).

painting come from the middle: the head of Jesus. This is the same in ship design, our "Jesus" is the middle of the design spiral: the optimised ship design. All the lines, the design aspects, are integrated and evaluated at the same time [40].

In the early design stage, simulation can be useful to enhance conceptual system design efficiency, particularly for novel systems without predefined components and constraints. Using object-process methodology (OPM), one of the studies identified necessary components through functional definition, considering multiple objects for single processes and applying constraints to refine designs. The methodology compares multiple designs to understand their characteristics, addressing the initial lack of dynamic behaviour insights through system dynamics simulations. This approach creates a simulation model and characteristics network to map relationships between design variables, identifying contradictions and causal loops, and guiding design refinement. Applied to a floating offshore wind power system, the methodology effectively organised functions, differentiated design proposals, and strategically refined choices, demonstrating its capability in constructing models and deriving design proposals for new systems [48].

The relations between the design aspects and parameters to be integrated, like weight, stability, costs, safety and contract requirements, can be seen as a "network of nodes". Finnish NAPA has integrated this idea into the 3D model of the ship in the initial design phase. The results of the calculations of one aspect are the input for the calculation of other aspects. This node network approach can develop into a setup for algorithmic iteration to find the optimal situation [56].

Additional to balancing the design aspects, the V-model provides an important calibration of the real-life situation. In the left part of the V, the design process constantly keeps the operational and production phases in mind to get an optimal design that meets reality. In every stage of the production, testing and operational phases, valuable information is communicated back to the design process to verify and validate the design to ensure that it meets the specified requirements and objectives [43].

Integrating design aspects by integrating systems

With the integration of several design systems (own and from external parties) an optimum can be found with certain parameters and constraints/limitations through design simulation, even when there is little room to optimise. This can be done for different operating profiles and loading conditions. The next step is to integrate the digital shipyard for evaluation of the space and possibilities of the construction site. A combination with AI and possibly chatbots can even further digitalise the ship design. Siemens presented a general framework of optimising hull geometry by integrating intact stability analysis and high-fidelity resistance analysis. This is facilitated with Simcenter HEEDS by integrating Siemens NX for geometry modelling, Siemens FORAN for intact stability analysis, and Simcenter STAR-CCM+'s CFD solver to conduct hydrodynamic resistance analyses [40].

Another attempt to integrate design software was developed in India, where a holistic design and optimisation approach was developed for the generic design of an electric river transit ferry. The approach uses a Python-based tool, which is integrated with key design tools such as CAESES (hull form generation/parameterisa-

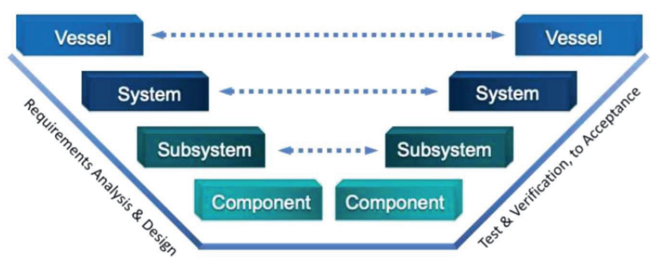

Figure 7. The V-model (image by Siemens [43]).

Figure 8. Different views by different bills of materials (image National Institute of Maritime, Port and Aviation Technology, Japan [31]).

tion), SHIPFLOW (potential flow), NAPA (stability), OpenFOAM (RANS), NavCad (propeller design) and other Python-based submodules. The primary inputs used in this methodology are user requirements and operational constraints. Principal dimensions are defined considering the route-specific restrictions, and CAESES is used to generate various hull forms adhering to these constraints. Simultaneously, key naval architectural calculations and battery sizing are performed seamlessly by integrating with Python sub-modules or by coupling to external tools. A user generated data set was used to run a test case. The results showed significant time savings compared to traditional iterative methods [20].

For data exchange in the 3D model, the Open Class 3D Exchange (OCX) standard is increasingly accepted and applied, especially in data exchange with class societies. This provides a timely opportunity to, for example, re-evaluate the role of FEA in the ship design and approval. Based on classification rule FEA and reporting requirements, a minimum dataset is needed to replace typical paper-like PDF reports with a model-based FEA report [29].

Data needs to be contextualised through the lifecycle

Most yards request product lifecycle management (PLM) systems to provide a "holistic view" or "single source of truth". The reason is, that all vessels require several different design and manufacturing disciplines, which often lock their data in domain-specific data silos. This information should be merged and published to enable better visibility. Data models and PLM systems must achieve a balance between established ways of working and new capabilities [8].

An integrated 3D model, with all its components, has a much longer lifetime than the traditional design. When all the information is connected to components, a single pane of glass for every viewer is needed. Every viewer has a different perspective, scale and need for a focus on a part of the data and information. Also, in different phases of the process, different information is needed. Another advantage of the focus on components is that at the end of the process, a digital ship business is delivered to the shipowner. In one of the papers, an "enterprise digital backbone" is presented to share information throughout the complete process. In this process, the focus on component information is key instead of sharing output of subprocesses in separate deliverables like documents and files [39]. These "views" have to be supported by a solid data and communication structure. One paper presents a communication structure where there is not one bill of material (BOM), but several different "views" in every stage of the process, like the engineering BOM (E-BOM) and manufacturing BOM (M-BOM). In the current shipbuilding industry, a "parts list" is created for manufacturing and procurement of parts, and these parts lists are compiled from 2D drawings or 3D CAD models as a result of product design. In the new method, the configuration of the parts of a product are designed in advance, and then the shape, dimensions and arrangement, and so on are designed for each part. Product development proceeds in association with the parts on the pre-designed part configuration. This enables data integration between design, manufacturing, procurement, and other operations with the parts as the key, as well as advanced product development management with the granularity of the parts [31].

Another study proposed a data model that was defined from exist-

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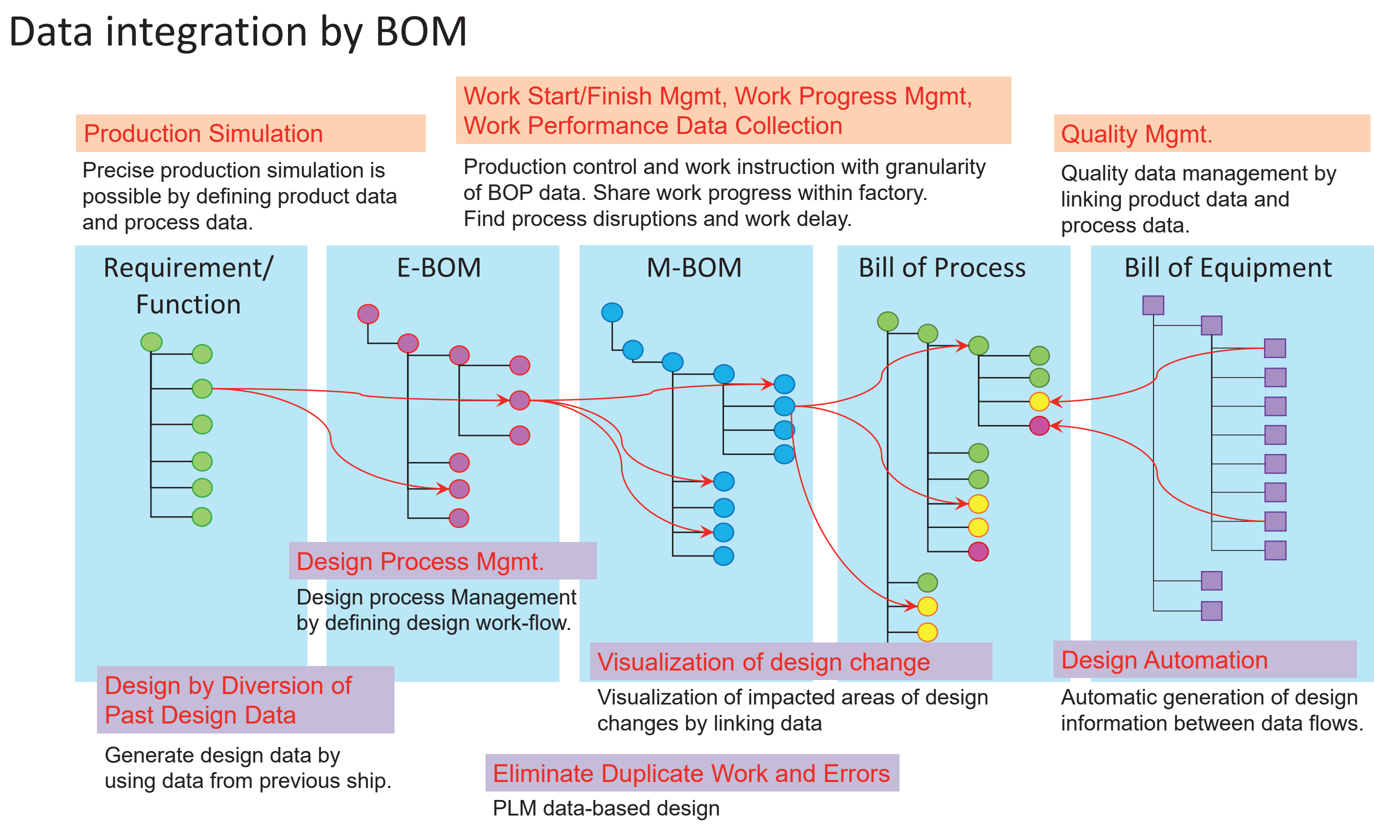

Figure 9. Contextual reporting (image Cadmatic [34]).

ing data and used a prediction of relations of components using machine learning and calculation methods. The objective of this research is to facilitate the acquisition of tacit knowledge by inexperienced ship designers through the utilisation of specification data and designer insights. A machine learning model was developed using a number of features, including Cramér's V, centrality measures and cosine similarity. The study identified component relationships, which led to the creation of a design structure matrix (DSM) and the formulation of new module proposals. These findings support the effectiveness of cosine similarity and matrix descriptions in system design [30].

Defining a data structure facilitates the simulation of the shipbuilding process, accounting for modifications to the design and construction complexities. In one paper, production process data can be generated automatically by inserting task nodes for "decompose, combine, or state-change" between product nodes. Each production department manager can then define their detailed process data as a project model, specifying management scopes and adding information about facilities and workers. This modelling data allows for process simulations to produce updated production plans for each department, ensuring all plans are automatically revised when the design plan changes, thereby maintaining inter-departmental relationships [53].

The different perspectives can be visualised by Cadmatic eShare, where team members can access published information from any system using typical web-browser skills. With many information systems now providing APIs based on standardised frameworks, data can be read immediately. This is done by the use of interfaces to read data and documents creating a unified picture of a project accessible via web-browser to teams and departments across the project. Capture of maturity and comments allow progress to be understood and objections highlighted [34].

REFERENCES

An almost complete overview of the developments in the papers is presented here and in part 1, which was published in our November issue. More information about a specific subject can be found in the papers, of which a list can be found on our website, https://swzmaritime.nl/news/2024/11/13/references-of-iccas-article-in-swzs-november-issue/

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