PREDICTING THE FUTURE

Developments in digitalisation at ICCAS – Part 1

Designing a ship for the best operation in the maritime ecosystem it's in, is all about predicting the future. New technologies make predictions more and more accurate. By "playing" with different scenarios, possibilities are endless. At the International Conference on Computer Applications in Shipbuilding (ICCAS) in Genua in September, a lot of innovative solutions were presented.

Realistic predictions can be realised by a digital twin of a ship or shipyard, connected to the real world. Together with the use of artificial intelligence (AI), the work of an engineer becomes more engaging and accurate. To realise an accurate digital twin, cooperation and integration of information is crucial. This article gives an overview of the developments and the valuable discussions that emerged at ICCAS. In the next edition of SWZ|Maritime, more about connecting the virtual world to the real one will be revealed in part two of this report.

Industry 4.0

The maritime industry is entering a new industrial revolution: Industry 4.0 (figure 1). Where mechanisation and steam power in the eighteenth century, assembly lines and electrical energy in the nineteenth century and electronics and computers in the twentieth century created a transition to a new industry, this century, cyber space, internet and AI will lift the industry to a new level.

One of the keynote speakers, Aldo Zini, Senior Researcher at Fincantieri Shipyards, said: 'The virtual prototyping of the ship has been used for many years, starting at the beginning of the century. The main idea was to implement a virtual representation of the ship and its systems able to behave reliably through simulation. But a crucial ingredient was missing: the interaction with the real ship. Today, new technologies pave the way for connecting the virtual world with the real one. The naval industry has witnessed a significant transformation, transitioning from traditional virtual prototyping applications to the more sophisticated paradigm of digital twins of ship, shipyard and even a complete digital maritime ecosystem.' [3]

Simulation in the virtual world

CAD systems have long been instrumental in streamlining the ship design process. However, the advent of Industry 4.0 has necessitated their evolution to meet the demands of a rapidly changing landscape. Modern CAD tools are not merely digital drafting platforms, but sophisticated systems capable of integrating with other Industry 4.0 technologies, such as Internet of Things (IoT), AI and cloud computing. These tools enable seamless collaboration, iterative design processes, and real-time feedback [44].

The traditional perception of a digital twin in shipbuilding is as an initial CAD design to support the physical build process. More recently, it has become a system in which data from the operational ship is maintained in approximately real time. Placing this real-time

Photo: In the middel of the picture, the ICCAS venue. This is the long building with the red roof, in the middle of Genoa harbour (photo Annelinde Gerritsen).

digital "shadow" within a realistic environmental simulation enables its use for planning and scenario testing, and for predictive maintenance scheduling [23].

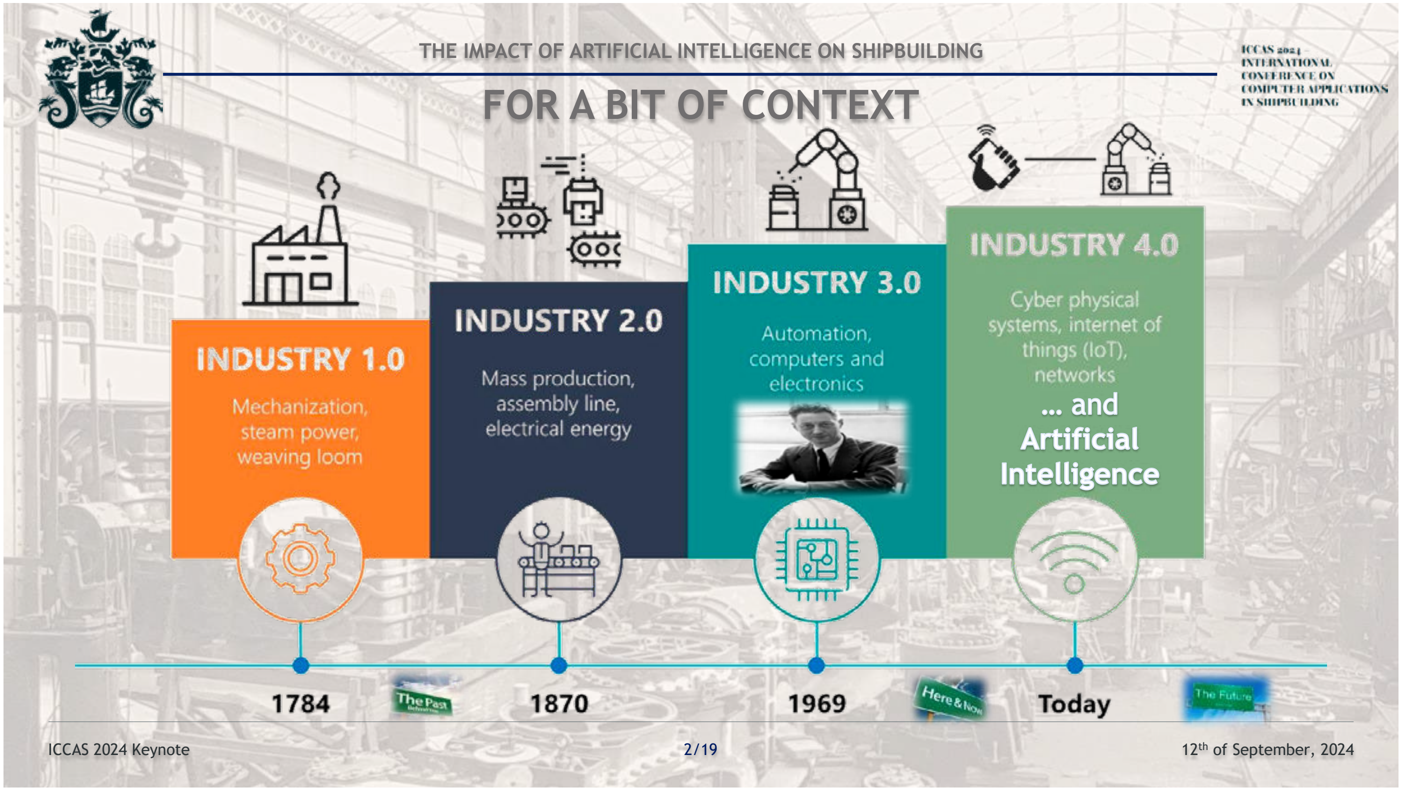
There is a strong need for improved data management and the development of user-friendly simulation solutions that allow for easy implementation and standardised model creation. Discrete event simulation (DES) has long been used in shipbuilding planning, particularly for material flow. The simulated processes and results can be presented transparently using 3D virtual reality (VR) viewers, and there is substantial untapped potential in exploring new applications for training and education. While DES shows significant potential, it also presents various challenges. Incorporating sustainability and environmental impact into simulations should be standard practice, but needs a holistic modelling approach [11].

A digital twin maintains data from the operational ship in approximately real time

As an example in one of the studies, DES is used in an AI-based optimisation system for quay arrangement, which was developed in four steps. Firstly, the standardisation involved defining essential information and constraints necessary for the quay arrangement plan. This step ensured the system could effectively solve spatial arrangement problems in schedule planning using simulation methods. Secondly, the automation introduced a DES-based simulation algorithm to automate quay arrangement planning tasks previously handled manually. This approach leveraged predefined constraints to prevent human errors and expedite scenario planning. Thirdly, for optimisation, a reinforcement learning model was employed. The model used the DRQN algorithm to tackle local optimisation challenges found in the DES-based approach. This allowed for optimal planning on a global optimisation perspective and adaptation to new environmental factors, such as the introduction of new ship types [17].

Digital ships and shipyards

A physically large and technologically advanced system, such as a naval ship, can surely be identified as a complex system, where the platform and the combat system interact with each other and with the operational environment, towards multiple common objectives. Developed software provides a new methodology to perform trade-offs for selecting among the set of efficient design configurations the best one according to customer preference during the pre-feasibility phase early-stage ship design. In the simulation, SysML is used to model the system architecture, requirements, and variability, and to link them to an internally developed Monte Carlo simulation tool (ASNET) that can run design of experiments (DOE) to evaluate the system behaviour under different conditions [13].



THE IMPACT OF ARTIFICIAL INTELLIGENCE ON SHIPBUILDING

ICCAS 2024
INTERNATIONAL
CONFERENCE ON
COMPUTER APPLICATIONS
IN SHIPBUILDING

FOR A BIT OF CONTEXT

INDUSTRY 1.0
Mechanization, steam power, weaving loom

INDUSTRY 2.0
Mass production, assembly line, electrical energy

INDUSTRY 3.0
Automation, computers and electronics

INDUSTRY 4.0
Cyber physical systems, internet of things (IoT), networks
... and Artificial Intelligence

1784
1870
1969
Today

ICCAS 2024 Keynote
2/19
12th of September, 2024

Figure 1. Transforming to a new industrial revolution (illustration Siemens Digital Industries).

In simulation environments of ships in ports has been demonstrated that the use of real-time simulation greatly enhances the operational analysis and understanding of the performance of various design solutions, therefore facilitating a truly robust design development process to establish optimal and safe assets, both ships and port infrastructure in their totality, together with the development of associated operational procedures [59].

The European project EDINAF aims to design a digital warship using a data-centric infrastructure that enhances cooperation in the naval domain. Despite differing national requirements, EDINAF focuses on several key areas:

- Developing interfaces with parties creating "digital offerings" (digital factories providing various contributions).
- Ensuring the industrial organisation necessary for the digital ship's economic viability and sustainability.
- Establishing digital interfaces for crew and ship support, including hardware, software, and user assistance.
- Formulating data exploitation and transfer strategies for interactions between industrial and governmental players, while addressing confidentiality.
- Implementing comprehensive cyber protection for the ship, including attack analysis and recovery processes [26].

Additionally, the digital ship can be built in the digital shipyard. Dassault has created a visualisation of the complete shipbuilding process by introducing the "Smart Shipyard", as described in another article in this edition [55].

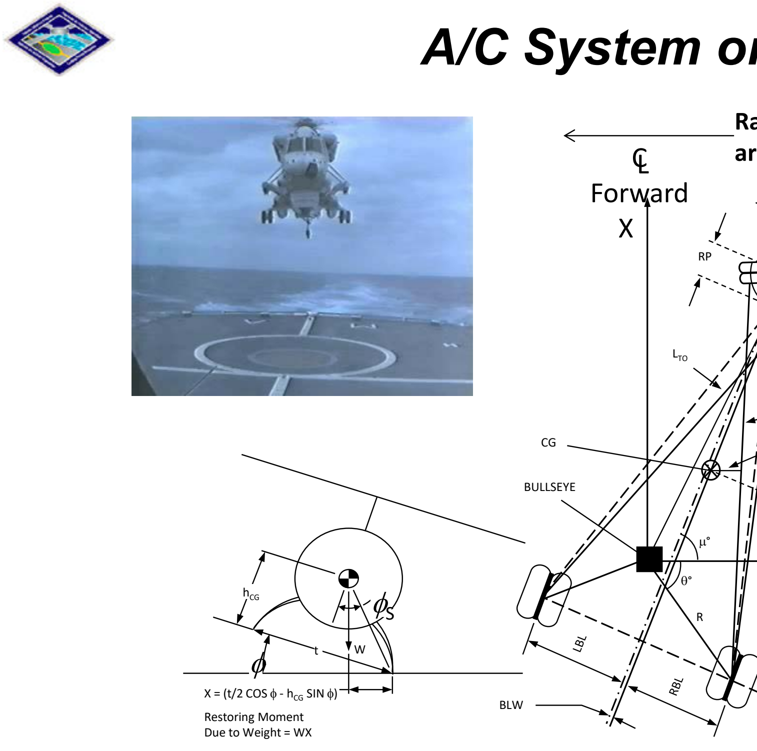


Figure 2. Forces on a helicopter when landing on a deck.

From simulation to AI

AI is generally defined as computer systems that perform tasks usually requiring human intelligence, for example, visual perception, speech recognition, decision-making, and text summary. A subset of AI is machine learning, where the performance of algorithms improves with experience. So-called deep learning is machine learning with highly complex models (perhaps billions of parameters), vast datasets and massive computing power [24].

As AI systems begin to be incorporated into ships, digital twins provide a new opportunity. A high quality digital twin embedded in a realistic environmental simulation presents the possibility of generating large volumes of training data for the AI systems, without the need for expensive sea trials [23].

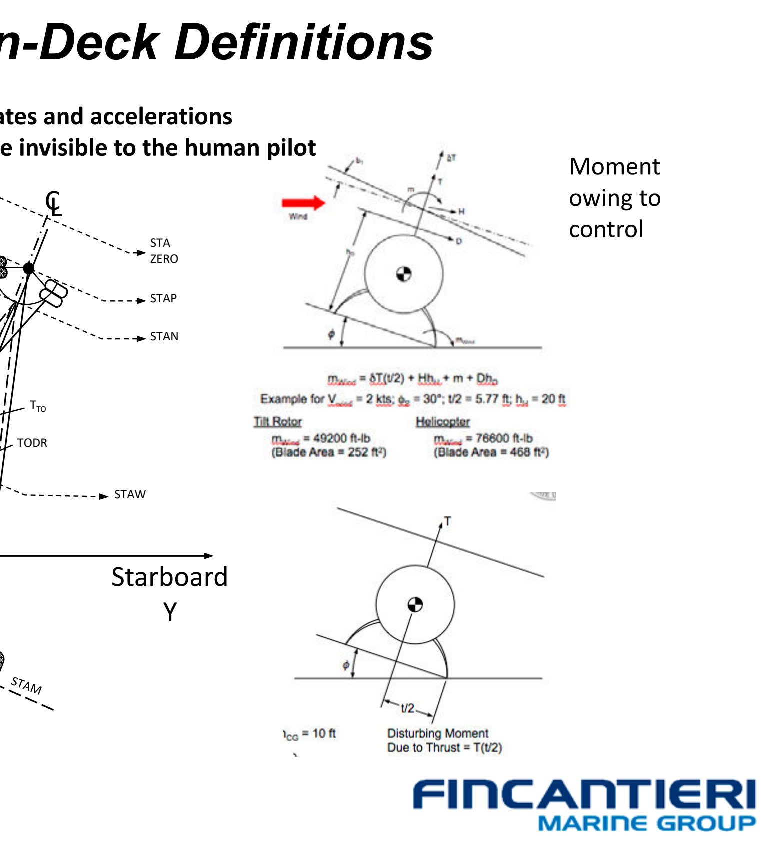
> By leveraging AI, the decision support system enhances situational awareness

The complexity of modern ships often results in technical personnel not fully understanding a ship's capabilities and in difficulties evaluating system-wide impacts of failures during both design and operational phases. Operational procedures frequently neglect all potential scenarios, posing risks in emergencies or with inexperienced personnel. One of the papers introduced a knowledge-based decision support system (DSS) designed to address these challenges using AI. The DSS assesses mission feasibility, determines necessary action sequences, and provides performance and autonomy measures to the personnel. By leveraging AI techniques, the DSS enhances situational awareness, performance monitoring, and, if possible, the path to disaster recovery in naval operations [2].

Launch and recovery with AI

Operations of launch and recovery of aerial vehicles, like helicopters, on a ship deck are among the most challenging tasks in the deployment of piloted and robotic air and sea vehicles. The sea is a chaotic system that can be hard to predict. In piloted aviation, a deck officer normally guides an arriving air vehicle to a safe deck landing. The deck officer uses the combination of visual cues and deck behaviour by "feeling the deck" to anticipate the deck's condition.

In automated operations, the approach is different. Humans can see displacement, but not accelerations. Numerical models are needed to properly predict a ship's motions and these simulations are then re-applied to optimise the ship and vehicle recovery interaction. Also, it is easier to tell the computer what to do then to tell the pilot what to do. The key is to find a balance in all the disturbing forces. Machine learning (ML) can be a useful tool in the definition of oper-



ations within dangerous conditions. A paper by Fincantieri describes the development of a simulation creating a reasonable representation of real-world operations of launch and recovery of aerial vehicles on a ship deck. The objective is to evaluate parameters like ship motion conditions, computing motion predictions with sufficient forecasted time to launch, recover and complete other motion sensitive tasks regardless of the seaway. This is achieved within a controlled environment permitting greater opportunity to evaluate a candidate system well before the system is brought to sea. Initial at-sea testing for both manned and unmanned air vehicles show a favourable tendency to reflect predictions made by simulated computations [4].

In addition to this paper, a study was presented about better predictions of the sea state under which a wide range of launch and recovery operations can be safely undertaken. With the use of quiescent period prediction (QPP), the shape of the sea's surface can be predicted at the operation site, for a short time into the future. QPP requires a deterministic measure of the sea surface profile remote from the prediction site together with a suitable wave propagation model and a vessel motion model [5].

Route optimisation with AI

Another example of the use of AI is a reinforcement learning approach for maritime route planning, considering ship dynamics and wind conditions. Reinforcement learning is suitable for route planning because it does not require prior knowledge. State and action are defined based on ship dynamics and a reward function is designed considering an initial route. To validate the effectiveness of the proposed method, it is compared with simulations in a virtual marine environment characterised by narrow waterways and numerous static obstacles. The results demonstrate that the proposed method achieves a smoother route and lower angular velocities [25].

Another study presents an optimisation-based approach to reduce fuel consumption and emissions, alongside a techno-economic analysis of a mid-life refit of an integrated real-time ship operation optimisation system (SOOS) on a typical container ship. It demonstrates that hydrodynamic performance can be significantly enhanced through trim optimisation and wave-induced roll stabilisation, allowing ships to reduce fuel consumption while operating effectively in adverse weather. The study assesses a newly developed voyage planner using vectorised simulated annealing (VSA), evaluating fuel consumption based on speed over ground influenced by ocean currents and wind loads. It also examines added resistance from waves and roll motion responses to ensure the consistency of fuel consumption results. The findings highlight the potential for "just-in-time" arrival at ports, leading to reduced fuel consumption, emissions, and improved schedule reliability. The minimal route determined offers approximately 3.5 per cent fuel savings compared to the direct route, which is promising given current fuel prices [47].

Other use of AI in shipbuilding

AI, like a chatbot, also has simpler, but still very useful, applications in shipbuilding. It can help make technologically complex text more understandable for daily use in communication – the author of this article made some use of this. But it doesn't always give the right answers, although it can give the user some suggestions for improvement. Chatbots are especially good in text search and creation.

In rules and regulations of classification societies, it is often hard to find the right section and a lot of time is wasted searching. Several solutions were presented to make this process more efficient. The RINA Italy Plan Approval Centre uses a chatbot in the ship approval process. The chatbot is asked a question and it answers with the right section in the rules and shows where it originates.

The Korean Register uses a search method based on semantic similarity using natural language processing (NLP) technology. They evaluated various NLP models to measure the semantic similarity between the dataset and search queries [21].

The Norwegian University of Science and Technology has done research on whether the use of large language models (LLMs) in general, and multi-agent LLMs in particular, can be combined with model-based systems engineering (MBSE) principles to increase the efficiency in developing design optimisation and simulation models. They proposed a step-by-step approach, starting with a textual narrative, capturing this in a unified modelling language (UML) model, then formulating this as a mathematical optimisation problem that is implemented into python code and solved. The main conclusion in this paper is that agent-based AI has the potential to be of useful

Technology is moving at a rapid pace. At ICCAS, lots of new developments in digitalisation were actively discussed (photo Annelinde Gerritsen).

assistance to designers in the early stage exploration phase, but still a lot of research has to be done to draw any strong conclusions on the applicability and usefulness of these technologies as part of an engineering design optimisation process [46].

AI also gives opportunities to improve the production process. By monitoring the voltage and current of the welding process, quality of the welding can be observed [7]. With laser scanning and an AI-based bead shape analysis system even detailed welding faults can be detected [52].

Data processing limits

There is a drive for companies to include AI in their products and in the development of their products. But AI should not be used without good reason, as there are risks and costs associated with its use that are not encountered in non-AI systems [24].

Simulation can help develop AI models by generating a wide range of conditions quickly. However, if the simulation closely mirrors what the AI model is trying to learn, it may not effectively train the model, as high-fidelity simulations could eliminate the need for AI. An exception arises when simulations are highly accurate, but computationally expensive. In such cases, creating an AI model as a surrogate can be beneficial.

A full digital twin, utilising real-time data, bridges the gap between simulation and reality. This involves continuously recording large volumes of data during the ship's operational time, rather than relying solely on dedicated sea trials. While this may not require significant computational power, it does necessitate onboard storage and likely a technical expert to maintain the data recording systems [23].

In the case of electrical power usage, it is estimated that using generative AI to deliver results uses 33 times the power of a standard system. This is the operational use, and does not include the resources required to train the models. The best starting point for introducing AI models into an organisation might be in the area of optimisation. These models are generally explainable and their results are testable, and, where multiple competing objectives are to be optimised simultaneously, they provide information to human decision-makers about the trade-offs between these objectives and the nature of that trade-off that is not otherwise available [24].

In the engineering process, a next step might be to connect a 3D model of a ship to a game engine, so the engineers can literally

"play" with different solutions. In one of the papers, the usability of an "Unreal Engine" as a day-to-day visualisation and ship model examination was evaluated, as was the gradual process of building a complete 3D parallel model that can be used as a starting point for the entire digital twin implementation. The main obstacle for "day-to-day" usage was the long time required for the data load [16].

With virtual reality (VR), applications such as virtual training systems and design collaboration tools can provide users with a more immersive experience. However, the enormous and intricate 3D CAD models used in shipbuilding and offshore platform design present significant challenges. Efficiently loading these massive files into VR applications while maintaining a smooth user experience requires advanced processing and optimisation techniques in computer graphics. Basic methods like level of detail (LOD) are necessary, but insufficient. Shipbuilding 3D CAD models consist of tens of thousands of parts. Rendering each part on the screen places a heavy burden on computer memory and the CPU. The memory usage of a whole ship is about 23 GB. To address these challenges, a Korean company proposed a method that utilises geometry simplification and presenting differently in every level of detail, thereby reducing loading times and controlling memory usage. This approach ensures a more seamless and efficient method for visualising shipbuilding 3D CAD models [54].

In the case of data collection, digital twins in the maritime sector face connectivity challenges due to high latency and low bandwidth, necessitating both local (edge) and remote (cloud) services.

A full digital twin bridges the gap between simulation and reality

Ships can be considered "moving edges" or "moving clouds" requiring robust integration of digital twin services to ensure functionality and data exchange.

Current gaps between service providers (such as data analytics) and data providers (for instance ship operators) need to be bridged through transparent data access and a common data infrastructure. Data connectors, both internal (linking ship data sources) and external (providing standardised, secure access to data), are essential to creating a maritime data space for efficient data sharing and decision support. By leveraging the IoT edge-cloud continuum and integrating advanced technologies, critical challenges in communication, data fusion, and vertical integration can be addressed [1].

The impact of AI on shipbuilding

On the last day of the conference, some good questions were addressed to the keynote speaker and an interesting discussion arose with the participants. The presentation of keynote speaker Dr Rodrigo Perez Fernandez, Senior Director for Software Engineering of Siemens Digital Industries showed that AI in the CAD/CAM/CAE industry has useful applications: It can analyse ("show me how to…"), generate ("create a model of…") and optimise ("which option solves…") the engineering process. Advantages are a significant improvement in efficiency, reliability, experience and optimisation.

AI can help designers do their job, it doesn't replace their job. Humans still need to direct AI systems and cooperation between parties is crucial. We still need the knowledge from a ship designer's point of view. Fears and prejudices about using AI can be minimised by introducing standards and ethical frameworks.

Several questions from the audience inducted an interesting discussion with the participants. Q: AI is all about quality of data, how do we train people to put in the right data and use the new technologies? A: We have to teach people to assess which information is right or not and how to filter the data. There already is a master's education where students are trained how to deal with data. Q: Isn't it risky that we get too dependent on AI and let the machine decide? A: People always have to have the knowledge and experience to solve problems. Q: Can data from different clients be integrated in the intelligent system of a shipyard? A: The system learns from the data that it contains, but when a new client is introduced, the system needs to be trained to meet the wishes and requirements of the specific client. Q: AI is only as good as the information it has, a lot of knowledge is "soft", how can we catch that? A: For AI to operate well, all the information on design and operation of the ship must be accessible and open. Cooperation is crucial. AI has so much to offer, but we have to be prepared to feed the system with all the relevant data. Most of the time, the shipbuilding industry is not inclined to share information. Sharing information doesn't have to mean that all knowledge is out in the open, by anonymising information mainly the system can learn. Q: How do we start that journey of trust? Who is the owner of the data? Who's going to pay the bill? A: We have to form consortiums of companies and authorities so everybody can learn. A new business model is needed that embraces openness in data sharing.

Together we will shape our future

This title of the conference says it all: digitalisation and innovation is not possible without cooperation. Data sharing remains a contentious issue; questions about ownership and access to data can complicate collaboration. The more we rely on digital, the more we become vulnerable, making integration of design and real-time monitoring even more crucial.

One major hurdle is the effective transfer of information, even among team members who know each other well. This transfer often relies heavily on deliverables and documents, making communication less fluid. Bridging these gaps requires boundary-crossing initiatives, where the context and workflows of different players are integrated. Digital twins offer a solution by creating a joint context and a single source of truth in a "digital ecosystem", which streamlines communication and reduces reliance on meetings that are now reserved for addressing significant challenges.

Preparing for the digital ship or twin means considering all aspects of the process and fostering a collaborative environment between humans and machines. This helps manage risks related to information sharing, cyber security, and quality management. Cloud technology further strengthens collaboration among distributed teams, offers robust security measures, and facilitates remote work, contributing to improved project outcomes and stakeholder satisfaction [6].

The digitalisation of shipbuilding extends across the entire maritime ecosystem, involving suppliers, subcontractors, and regulatory bodies. These digital technologies enhance connectivity and transparency within the value chain, accelerating innovation and ensuring compliance with evolving regulations and industry best practices. This shift represents a fundamental reimagining of how ships are conceived, designed, and built, aiming to unlock new levels of efficiency, sustainability, and competitiveness. As shipbuilders embrace digitalisation, they are set to navigate a future where innovation knows no boundaries and possibilities are limited only by imagination [43].

Digital transformation: A challenge of change

Digital transformation is a complex journey, often fraught with challenges. Studies show that only about five per cent of digitalisation projects meet their objectives, highlighting the difficulties organisations face. While thirty to forty per cent of success can be attributed to the technology itself, a significant sixty to seventy per cent relies on people – underscoring the importance of team engagement supported by digital tools [34].

> Encouraging a culture of challenge and collaboration will be key to success

The transition is not simply about adopting new technologies; it also involves a shift in mindset. This is not easy for everyone. Change can be met with resistance, particularly from those entrenched in traditional ways. Engaging these individuals in discussions about innovation is critical for fostering acceptance and collaboration. Don't be afraid to challenge and be challenged.

Ultimately, the holy grail is to have ships monitored digitally, which demands a complete rethinking of traditional processes. Shipyards that embrace open and fluid information will lead the way in this new era of shipbuilding. Engaging in discussions about these transformations and encouraging a culture of challenge and collaboration will be key to success.

To maintain momentum after conferences like this, ongoing communication and brainstorming are essential. Only then will we get that information flow between each other, keeping everyone aligned and engaged.

REFERENCES

An almost complete overview of the developments in the papers is presented here and in part 2 to appear next month. 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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