Proceedings of the 32nd European Safety and Reliability Conference (ESREL 2022)
Edited by Maria Chiara Leva, Edoardo Patelli, Luca Podofillini, and Simon Wilson
 Published by Research Publishing, Singapore.
doi: 10.3850/978-981-18-5183-4_J03-07-636-cd

Towards a Harmonized Framework for Vessel Inspection via Remote Techniques

Aspasia Pastra

World Maritime University (WMU)-Sasakawa Global Ocean Institute, Sweden. E-mail: asp@wmu.se

Tafsir Johannson

World Maritime University (WMU)-Sasakawa Global Ocean Institute, Sweden, Sweden. E-mail: tm@wmu.se

Remote inspection techniques (RIT) for performing inspections on the steel structure of ships are changing the landscape of ship inspection and hull cleaning. Patently, unmanned aerial vehicles (UAV) perform global visual inspections, ultrasonic thickness measurements and close-up surveys for ships undergoing intermediate and renewal surveys; magnetic crawlers can conduct ultrasonic thickness measurements and perform hull cleaning; remotely operated vehicles (ROV) can perform underwater surveys. Moving forward, efforts to maintain good environmental stewardship, especially at the European Union (EU) level will require not only the seamless integration of RIT, but also a guarantee that all techno-regulatory elements vital the semi-autonomous platform are streamlined into a cohesive policy framework materialized through multi-stakeholder cooperation. The aim of this extended abstract is to present some of the findings from research conducted by the World Maritime University-Sasakawa Global Ocean Institute (GOI) within the framework of the European Union H2020 BugWright2 project. The findings mirrored through this piece derives from research pertaining to: the qualitative assessment of international regime related to ship's safety, environmental control of pollution and survey standards; and comparative analysis from case studies regarding the regulation of robotics covering six leading maritime nations. To this end, discussed herewith are the techno-regulatory elements --- those that bolster support to a harmonized regulatory blueprint for semi-autonomous platforms in the maritime domain.

Keywords: Remote Inspection Techniques, Ship inspection, Maritime Policy, Drones, Remote Operated Vehicles, Magnetic Crawlers.

Introduction

Automated technologies have transformed the global economy and industries. The industry is witnessing a shift from manual assistance to progressive automaton --- one that could inevitably lead to full autonomy in the not-so-distant future. With cascade of innovative advancements, service robots become smarter, smaller, and cheaper, paving the way for a service revolution where service innovations have the potential to dramatically improve customer experience, service quality and productivity (Wirtz and Zeithaml, 2018).

The maritime industry is embracing automation which may be the pathway forward for the sector to achieve environmental compliance as well as a sustainable maritime future. Electrification, remote technologies, digitalization, and connectivity have been immersed in a continuous evolutionary process that converges the sector in a powerful combination destined to transform the way the industry moves people and cargo on the water.

Relevantly, over the last years, several maritime administrations have approved remote inspection techniques for inspecting vessels on a case-by-case basis, and when recognized organizations (ROs) have had a rationale to endorse that a specific survey could be conducted remotely. Remote inspections, as it seems, could be conducted through UAV, ROV and Magnetic Crawlers. The demand for unmanned vehicles capable of replacing traditional manual-based surveys is increasing as we speak (Nex et al. 2022).

Although the global commercial shipping fleet is rising, reaching 99.800 ships of 100 gross tons and above, the ageing of the fleet constitutes an environmental concern since older ships generate higher emissions (UNCTAD, 2021). RIT has the potential to contribute substantially to mitigating hull-fouling through regular cleaning of marine plants and animals on the submerged structures of a ship (Alexandropoulou et al. 2021, McClay et al. 2015). Moreover, shipowners could gain tremendous annual financial benefits of 190 million euros as the direct and indirect costs (i.e., the means of accessibility and the opportunity cost) are diminishing substantially (Robins, 2021). Other substantial advantages of RIT entail the:

- Improvement of safety at sea as RIT minimize dangerous tasks for inspection personnel, such as entering confined spaces and working at height;
- Reduction of the number of hours spent on board by inspection personnel that might facilitate the operation of the ship;
- Provision of high-quality data and images, making it easier for ship operators to follow up on hull maintenance and create a maintenance plan that can predict the requirements of individual vessels;
- Enhancement of the survey report that inspectors submit to ship owners/operators by accessing consolidated data for survey preparation and reporting; and
- Potential that the increased availability of digital data will contribute to the development of other Artificial Intelligence (AI) models and applications for improving survey time and quality.

Despite the various guidelines issued by the respective classification societies (i.e., ABS, and DNV), there are currently no standard agreed-upon procedures at the international level for the execution of class and/or statutory surveys by remote means. The international maritime RIT governance framework is fragmented, to say the least, and shrouded with both grey areas that impede the integration of RIT alternatives at both the regional and national levels (Johansson et al. 2022).

The quintuple helix is urged to cooperate at the international level and adopt both policies that can stimulate beneficial innovation, and measures that could safeguard people from risks emanating from automated technologies (Smuha, 2021). Therefore, it is recommended that a new output on the “development of a blueprint for remote inspections’’ be added to the work programme of the Sub-Committee on Implementation of International Maritime Organization (IMO) Instruments. Against the above backdrop, a set of strands constituting a regulatory blueprint was developed by the researchers of the GOI within the overarching framework of the European Union H2020 BugWright2 project that aims to change the European landscape of robotics for infrastructure inspection and maintenance.

2. Elements Integral to the Regulatory Blueprint

The focus of the proposed blueprint considers, in tandem, barriers, dynamic governance, techno-regulatory rules and requirements, policy framework impacts with regards to service robotics, mobile platforms and individual RIT. To that end, researchers have reviewed international agreements relevant to the ocean technology and climate change regime, intellectual property rights, and the certification requirements and standards pursuant to the International Organization for Standardization (ISO) framework. Subsequently, a state-of-the-art cross comparative evaluation on selected case studies regarding the regulation of robotics in the United States of America, the Netherlands, Canada, Norway, China and Singapore has been conducted with a view to carving out how leading maritime countries are paving the way to autonomous operations, more specifically inspections and cleaning through remote platforms. To satisfy the goals of the above evaluation, sixty (60) in-depth interviews conducted with policymakers, classification societies and subject matter experts engaged in the field of automation and remote inspection technologies.

All the key take-aways from the two individual strands of assessment have been carefully conceptualized to illustrate a set of current needs in the form of a draft regulatory blueprint, which could be fully exploited by concerned regulatory bodies, as well as national and international agencies that deal with RIT in Europe and across the world. A synthesis of the main elements is provided in the following section.

2.1 Element one: Stakeholder Cooperation

In the field of autonomy and robotics, engagement with stakeholders is crucial to responsible innovation practices (Leenes et al. 2017). Despite asymmetries, RIT calls for a ‘participatory turn’ of stakeholder involvement and a continuous process of learning and reflection.

Partnerships between and among stakeholders are needed to increase the successful deployment of RIT. At the governance level, there are non-human actors that interact with policies and regulations, and participate in effecting a sustainable transformation in relation to RIT (Johansson et al. 2021). These actors include the IMO, IACS, various Standard Setting Organizations and Patent Organizations --- all of which set the safety, environmental and security governance framework of shipping. At the operational level, the human-element includes manufacturers, service providers, classification societies, asset owners and insurance companies, which are directly or indirectly involved in the application of the policies implemented at the governance level (Johansson et al. 2021).

A policy regime that can adequately balance out the different needs of stakeholders could ideally ensure “trust” in the technology and facilitate its uptake (Smuha, 2021).

2.2 Element two: Uniform Definitions for Different Rypes of RIT and Degree of Autonomy

Uniform definitions are the common language for setting a solid foundation for understanding the various types, features and limitations of RIT. An effort to conceptualize RIT has been made by IACS (2016, Recommendations 42, Section 1.1). According to the provisions, RIT may include the ‘use of: Divers, Unmanned robot arm, Remote Operated Vehicles (ROV), Climbers, Drones and Other means acceptable to the Society’ (IACS, 2016, p.1). Therefore, while a common minimum standard developed by IACS has been developed, evidently, no minimum standard definitions on UAV, ROV or Crawler are provided. Despite the amalgamated placement of all types under the common term “Remote Inspection Techniques”, technological and other differences will stay discernable since each technique differs in terms of task, outcomes and environmental conditions (Johansson et al. 2022).

Another term that should be clarified is one that relates to ‘close-up survey’, i.e., survey where the details of structural components are within the close visual inspection range of the surveyor and normally within reach of hand. Nowadays. classification societies approve service suppliers to provide close-up surveys using RIT, such as drones, climbers or remotely operated vehicles (ROVs). That said, when using RIT, the surveyor attends the details of the close-up inspection through a live video stream and the structural components that are not within hands reach. A revision of the definition of close-up survey is in order.

The “degree of autonomy” of these systems is also in need of conceptualization. The current stage of RIT is subject to “supervised autonomy” or “semi-autonomy” given that an operator shall remotely operate the technology in question. Over time, RIT might be fully autonomous and capable of functioning without human interference. The “degree of autonomy” is a stress on carving out the level of the autonomous systems in a fashion similar to what has been done for Maritime Autonomous Surface Ships (IMO Doc. MSC 100/20/Add. 1, Annex 2). Such a categorization could help keep track of the advancements toward autonomy, assisting classification societies with future potential revisions (Johansson et al. 2022).

2.2 Element 3: Proof of Concept

RIT will need to be considered with the objective of achieving at least equivalency with a traditional survey, with safety always being the primary consideration. This verification should be carried out in controlled environments where repeatable tests can be performed (Poggi et al. 2020; Pastra et al. 2022). Classification societies should get involved in extensive testing and establish the so-called “proof of concept” to ensure that these technologies provide safer and even higher-quality evidence in the survey process whilst offering equivalent benefits to shipowners and operators. To boost the robustness of these systems, more test-based statistics and data comparison is required to prove that the new technology is adequately safe and reliable for mass deployment (Pastra et al. 2022). For example, classification societies should conduct trial inspections on the same vessel using an ROV and cross-checking the data gathered against that which has been obtained by a diver. Cracks identified by airborne or underwater images should be compared to traditional counterparts for further check and balance.

2.3 Element 4: Risk Assessment Frameworks

During inspections, several safety issues, such as cleaning, ventilating, lighting and setting up of structures, are considered before an onboard survey is initiated (Poggi et al. 2020).

A risk assessment process that includes a flow chart could assist classification societies in determining whether a physical inspection is necessary. A common risk assessment framework for ship eligibility for remote inspection should be developed based on the age of the vessel, hull condition, severity of corrosion, type of survey, areas to be inspected, ship location, environmental conditions in the area and approved service suppliers. Classification societies should consider remote surveys on a case-by-case basis. If the classification society’s risk assessment enables the remote survey, the organization executing the remote inspection should conduct another round of risk assessment to identify any potential hazards to the planned inspection and subsequently, provide mitigation measures. This risk assessment should include risks associated with hazardous areas, payload of the machine, battery storage, operational accidents, dropped object risks, collision, unexpected interruption of the pilot operation and communication control links (ABS, 2019; CCS, 2018).

2.4 Element 5: Data Governance and Management

“Data governance” is deemed as the allocation of responsibility and shared decision- making over the management of data assets (Earley et al. 2017). In other words, data governance concerns policy-making decisions for corporate data, while data management is the tactical execution and monitoring of governance-related decisions (Khatri and Brown 2010, Johansson et al. 2021).

A data governance framework is essential to set the processes which safeguard critical data asset and how they are formally managed throughout the enterprise and between enterprises (Sarsfield, 2009; Al-Badi et al. 2018).

Good data governance and management boost “trustworthiness” within the ecosystem comprised of technology and the human-element, i.e., the ship owner, service provider, and classification societie (Pastra et al. 2022). Clear terms about data quality, ownership, copyright, collection, preservation entity, storage, security measures and data post-processing should be included in the form of a contract signed by the ship operator, class society, and service supplier (Johansson et al. 2021). The roles and responsibilities related to data ownership, quality, storage, security and sharing of information require an in-depth review of all private contracts developed by service suppliers. What is conclusive is the need for reliable mechanisms that ought to be forged by service suppliers to ensure long-term usability of data and metadata that belongs to an asset (the ship) that is involved in commercial activities (Johansson et al. 2021).

2.6 Element 6: The human element

Autonomous RIT will grow in the future broadly owing to advanced algorithms, collision avoidance systems, miniaturization of onboard sensors and concurrent work in the domains of robotics and computer vision (Nex et al. 2022).

Nonetheless, at its current stage, inspection using RIT is conducted in the presence of the attending surveyor. Human oversight remains as a safety-net throughout the deployment lifecycle of the RIT. Ergo, the human-element cannot be ignored. Human presence is the common denominator in all existing technologies and until technological developments reach the stages of “full autonomy,” human intervention will remain as a part and parcel of the operational system (Pastra et al. 2022). The survey inspection procedures, and most importantly, the training schemes of surveyors must be adequately aligned to match the level of sophistication required to carry out services using respective RITs (Pastra et al. 2022).

2.7 Element 7: Safety and Liability

Robots are products; RIT are products; they are not “person” or “beings” from an ontoligcal sense. A legal framework, therefore, should be applied to govern the usage of products (Alexandropoulou et al. 2021). In short, products must be regulated. Risks ranging from dropped object, collision or lost link, and defective products, *inter alia*, call the need to solve RIT-induced liability issues through existing regional or national policies (Johansson et al. 2022). RIT are operated using (battery-produced) “electricity”, which is viewed as a product in accordance with Article 2 of Directive 85/374/EEC (Johansson et al. 2022). According to Article 1 of the Directive, the producer shall be liable for damages caused by a defect in product so developed. Article 7 of the Directive renders the producer/manufacturer the opportunity to resort to the defense mechanism under specific conditions.

The Original Equipment Manufacturers (OEMs) of remote technologies should follow internationally agreed and accepted requirements for safe commercial operations (i.e., ISO

Standards). Whether a manufacturer is concretely liable will depend on relevant international or industry standards and whether the product specifications have successfully followed those standards. Manufacturers for RIT, during the design phases should ensure that connectivity will not directly compromise data accuracy and safety of the product. In parallel, manufacturers should ensure transparency, accountability, responsibility for all the intelligent information technological systems they develop. Certified products according to international standards should be provided by manufacturers and utilized by service providers. Service providers should ensure the safety standards of the equipment, including hardware and software, during the selection and maintenance phases. These systems should be rated for their intended operational environment (intrinsically safe in hazardous areas, operational wind speed, etc.).

The growing degree of autonomy inevitably raises the question of who is responsible if an RIT "violates" a contractual obligation; therefore, clarity is needed with respect to the responsibilities incurred in connection with the usage of remote systems. Clear provisions in the form of a contract should specify the liable party (manufacturers, developer of the AI system or pilot of the drone) in different scenarios when a remote system operated by a pilot crash and consequently, causes damage. Different scenarios include but are not limited to collisions with asset structures and animals, collisions due to malfunction of the equipment or cases where visual line of sight (VLOS) is not maintained.

The service suppliers should secure third-party public liability insurance and/or professional indemnity insurance to protect themselves against legal liability for property damage or injury.

Conclusions

National flag state authorities, classification societies and ship owners are steadily adapting to RIT-based solutions, especially during the COVID-19 pandemic due to the special challenges caused by restricting human-presence on board ships (Johansson et al. 2022). However, the absence of a uniform international framework for remote inspections has led to their approval, and as mentioned before, on a case-by case basis.

Introducing new technologies in the maritime sector requires the cooperation of various stakeholders to carry out a comprehensive process to amend existing instruments or develop new policies.

In the field of robotics, "soft law" approaches and codes of conduct enhance the level of acceptability for all the different stakeholders, increase the chance of self-enforcement and enable a shift from classic or responsive regulation to smart regulation (Leenes et al. 2017).

This paper identifies a framework with seven main elements that could be taken into consideration when developing a blueprint or guidelines in the form of Code of Conduct. As IMO member states are gearing up for dialogue and discussion for guidelines, it would be worth considering the basic elements that need consideration at the international level. These elements are robust stakeholder cooperation, uniform definitions, extensive testing, establishment of a risk assessment process, data governance, human element and liability, serving as a plinth for regulating maritime robotic and autonomous systems before unleashing. Otherwise, full potentials of the system may be impaired due to both foreseen and unforeseen bottlenecks. The elements discussed in this paper are consistent with the strategic direction of the IMO, which aims to implement and enforce the provisions of its regulatory instruments and integrate technologies within its environmental and safety framework in an effective and efficient manner.

References

Al-Badi, A., Tarhini, A. and Khan, A. I. "Exploring big data governance frameworks", *Procedia Computer Science* 141, (2018): 271-277. https://doi.org/10.1016/j.procs.2018.10.181

Alexandropoulou, V., Johansson, T., Kontaxaki, V., Pastra, A., and Dalaklis, D. "Maritime Remote Inspection Technology in Hull Survey & Inspection: A Synopsis of Liability Issues from a European Union Context", *Journal of International Maritime Safety, Environmental Affairs and Shipping* 5, no 4 (2021): 184-195.

American Bureau of Shipping (ABS), "Guidance Notes on the Use of Remote Inspection Technologies", (2019), https://ww2.eagle.org/content/dam/eagle/rules-and-guides/current/other/242-gn-remote-inspection-tech/rit-gn-feb19.pdf

China Classification Society (CCS) "Guidelines for Use of Unmanned Aerial Vehicles", (2018), https://www.ccs.org.cn/ccswzen/articleDetail?id=201910000000003817

Earley, S., Henderson, D. and Data Management Association. *DAMA-DMBOK: Data Management Body of Knowledge* (NJ, USA: Technics Publications, LLC: Bradley Beach, 2nd ed., 2017)

EU Product Liability Directive 85/374/EEC, 1985, *Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products*, OJ L 210, 7.8.1985, 29–33

International Association of Classification Societies (IACS, 2016) *Rec 42 Guidelines for Use of Remote Inspection Techniques for surveys*, https://iacs.org.uk/publications/recommendations/41-60/rec-42-rev2-cln/

IMO Doc. MSC 100/20/Add. 1, Annex 2, *Framework for the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS),* Dec. 7, 2018, ¶ 1 and IMO, MSC 99th Briefing (2018), http://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-MASS-scoping.aspx

Johansson, T., Dalaklis, D. and Pastra A. "Maritime Robotics and Autonomous Systems Operations: Exploring Pathways for Overcoming International Techno-Regulatory Data Barriers", *Journal of Marine Science and Engineering* 9, no. 6 (2021), https://www.mdpi.com/2077-1312/9/6/594)

Johansson, T., Skinn, J, Dalaklis, D. and Pastra A (2022 in press) "Harmonizing the Maritime Service Robotics Techno-regulatory Regime: Six Blocks of Influence for Good Environmental Stewardship", *Intersentia,* Cambridge University Press (TBC).

Khatri, V., Brown, C.V. "Designing data governance". *Commun. ACM* 53, (2010):148–152.

Leenes, R., Palmerini, E, Koops, B.-J.,Bertolini, A., Salvini, P. and Lucivero, F. "Regulatory Challenges of Robotics: Some Guidelines for Addressing Legal and Ethical Issues", *Law, Innovation and Technology* 9, (2017): 1-44, https://doi.org/10.1080/17579961.2017.1304921

McClay, T., Zabin, C., Davidson, I., Young, R., and Elam, D. "Vessel biofouling prevention and management options report", Homeland Security, March 2015, https://apps.dtic.mil/dtic/tr/fulltext/u2/a626612.pdf

Nex , F., Armenakis, C., Cramer , M , Cucci , D A , Gerke , M , Honkavaara , E , Kukko , A , Persello , C and Skaloud , J. "UAV in the advent of the twenties: Where we stand and what is next " , *ISPRS Journal of Photogrammetry and Remote Sensing* 184, (2022): 215-242, https://doi.org/10.1016/j.isprsjprs.2021.12.006

Pastra, A., Schauffel, N., Ellwart, T. and Johansson, T. "Building a Trust Ecosystem for Remote Technologies in Ship Hull Inspections", *Journal of Law, Innovation and Technology* 14, no.2, (in press: available September 2022).

Poggi, L., Gaggero, T., Gaiotti, M. Ravina, E and Rizzo C.M. "Robotic inspection of ships: inherent challenges and assessment of their effectiveness", *Ships and Offshore Structures* 17, No. 4, (2022): 742-756, https://doi.org/10.1080/17445302.2020.1866378

Sarsfield, S.,*The data governance imperative* (IT Governance Publishing, 2009).

Wirtz, J. and Zeithaml V. "Cost-Effective Service Excellence", *Journal of the Academy of Marketing Science* 46, no. 1 (2018): 59-80.

ROBINS, "Performance Standards and Cost Benefit Analysis" (2021), https://www.robins-project.eu/download/

Smuha N.A (2021) "From a 'race to AI' to a 'race to AI regulation': regulatory competition for artificial intelligence", *Law, Innovation and Technology* 13, no. 1 (2021): 57-84, https://doi.org/10.1080/17579961.2021.1898300

UNCTAD, "Review of Maritime Transport" (2021) https://unctad.org/system/files/official-document/rmt2021_en_0.pdf