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With Regard to the Autonomy in Maritime Operations – Hydrography and Shipping, Interlinked

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ABSTRACT: With change being the only thing that is constant, modern world is undergoing a disruptive change to many aspects of everyday life. Covering 70% of our planet, oceans and industries connected with them are of no exception. The apparent drive towards autonomization in shipping will not only change the way vessels are navigated, but will affect virtually all services needed for the vessels to be navigated. These include not only the design of ships themselves, training of their crews, remote supervision of onboard processes, but also the extremely important - yet not always appreciated - domain that allows for a safe navigation: maritime hydrography. This paper discusses some insights on how the autonomous vessels and future hydrographers may benefit from each other.

1 INTRODUCTION

The maritime world is changing more rapidly than ever before. Decarbonisation, globalisation, digitalisation and last but not least – pandemic-related economic crisis resilience-seeking are just few of the trends affecting our entire civilization. And the maritime industry is not immune to these trends. As a matter of fact, it is a driving force for some of them – just to note that a vast majority of global trade is done by the use of merchant vessels, thus allowing for globalisation of commodities flow.

Meanwhile, the digitalisation of shipping consists not only in improved data exchange processes among involved parties, big data analysis and utilization of block-chain technologies [1]. The ultimate goal (at least for some of the industry actors) is to make vessels navigate themselves across the oceans safely and efficiently [2]. In order to achieve this, a huge change would be required in multiple aspects of global shipping industry such as: legal system, education and training, hull and equipment design, external services. Among the latter there are not only insurance or communication, but also hydrography [3].

In the age of ECDIS (Electronic Chart Display and Information System) being compulsory for most of the sea-going vessels, the art of chart-work may seem somewhat forgotten, at least by younger generations of navigators [4]. This however does not change the fact that a huge workload, know-how and a sense of art must be dedicated to enable ECDIS to present what it is to present: a model of vessel's surroundings and for a navigator to develop what (s)he is to develop: a situational awareness [5]. From her/his perspective, this complex process of converting topography into a digital file presented on a screen is done somewhere in a background and only its effects are visible. No further consideration can be paid to the process during bridge watch that consumes all the mental capabilities of the navigator. With ships gradually becoming autonomous or unmanned, this exposure to the effects of hydrographers' work will diminish even further – but not its extreme importance.

The drive towards autonomy is also visible in hydrography itself with some operations already being performed by autonomous equipment – airborne, surface and submersible [6]. The rationale behind this trend lies in improved operational capabilities, lower cost and comparable accuracy.

With the trend of autonomizing operations of hydrographers as well as navigators – the creators and users of hydrographic data (see Fig.1&2.) – potential synergies and overlaps can be sought for the benefit of both parties.

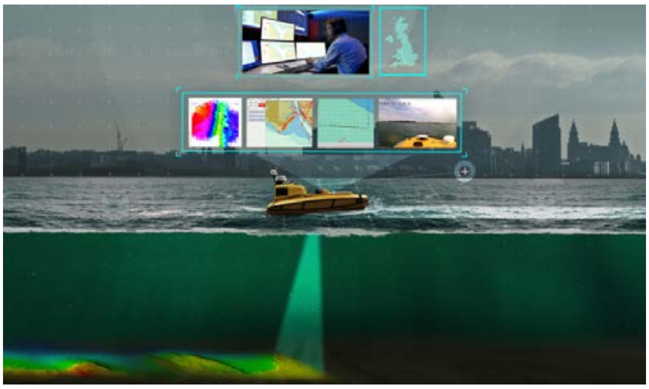

Figure 1. Autonomous Surface Vessel for bathymetry mapping, note remote operators' station on top [7]

Figure 2. Remote operation station for autonomous ship, note nautical chart displayed [8]

2 STATE OF THE ART

Autonomy is defined as the ability of the system to act without direct human intervention [9]. As a matter of fact, it can take many facets or degrees to which a system can operate autonomously [10]. All in all, even the most sophisticated system can eventually reach a point where a human action is required: maintenance or remote control, for instance.

The idea of a remotely controlled boat has first been published by Nikola Tesla as early as in 1898 [11]. However, the technological progress made autonomous boats feasible only recently [12], [13]. While there is a multitude of potential applications, several were explored to a greater extent than others. Among the former are remote sensing including hydrography [14], [15] and military applications [16]. Meanwhile, commercial shipping lags behind [17], [18], potentially due to the necessity of involving greater number of actors into the operations, global scale of operations, as well as legal issues [19].

Regardless the purpose, an autonomous boat is to achieve it without or with limited human intervention. To this end, this means that a sophisticated control system shall be developed to move the vehicle around and enable it to fulfil its mission. In order to achieve this, the mission shall be defined and resources for such completion provided, too. On top of that, a situation awareness module shall be implemented so that the vehicle does not end up colliding with an obstruction or other vehicle operating in the same area. On the other end of the spectrum, it can be lost forever at vast areas of the ocean, floating endlessly, dead in the water.

Hydrographic drones can operate on surface or underwater. Depending on the purpose, they can be equipped with echo-sounders, side-scan sonars, sub-bottom profilers or other equipment. A variety of technical solutions for control exist, including remote one as well as full autonomy [20]. They can relay the obtained data or store it on board for future transfer.

Meanwhile, autonomous merchant ships are envisaged to haul cargo between ports. Here too, a variety of concepts exists with different approaches to the issue of crewing, autonomy levels, and means of control. However, with ultimate plan of allowing for world-wide operations, a magnitude of social and technical challenges is greater. In order to solve these, a concept of shore-control centre (SCC) has been developed – a shore-based facility from which fleets of ocean-going vessels could be supervised and controlled. The rationale behind implementation of autonomous vessels lies in improved working environment, cost reductions, improved safety, and reduced environmental impact [21].

Both hydrographic drones and merchant vessels are similar with respect to the general concept of performing complicated tasks autonomously and have similar design philosophy. There are, however, important differences between these domains including that: (1) their missions are different and (2) technological readiness of the solutions is different (see Fig.3).

While there are multiple units successfully used in hydrography [6], [23], autonomous merchant shipping is a relatively new concept with only few vessels operational worldwide, mostly as prototypes or a proof-of-concept [17], [24]. More importantly, most of these trials are done in restricted waters while it is expected that autonomous merchant vessels (also referred to as Maritime Autonomous Surface Ships, MASS) will exploit its full potential during ocean passages rather than in near-shore navigation [25]. The delayed development of the merchant shipping concepts provides some important benefits, such as learning from the problems apparent and solved through the development of similar domains [12], [26]. Having skipped at least some of the childhood diseases, the development of lagging domain can be smoother.

Figure 3. An operational hydrographic drone (top, [6]) and an autonomous vessel under construction (bottom, [22])

3 A SYNERGY EMERGING

As the purpose of operating hydrographic drones is to gather data related to environment, these platforms shall move along pre-programmed paths (profiles) to allow on-board sensors to detect sea bottom features with sufficient reliability and accuracy. In order to meet international standards for accuracy of bathymetry data [27], all environmental sensors shall operate with maximum efficiency – not only side-scan sonars, echo-sounders etc., but also position-fixing devices.

Meanwhile, the very purpose of merchant ships, including prospective autonomous ones, is to haul their cargo between ports. They also need to meet certain requirements pertaining to the precision of navigation as well as equipment installed on board and its operation. With the aim of making autonomous merchant vessels at least as safe as conventional ones [28], it can hardly be imagined that these standards are loosened for this novel and yet-to-be-proven technology. Rather, the prospective MASS will be packed with redundant, cutting-edge environmental sensors and other kinds of equipment to ensure the reliability of the processes [5]. Data from such sensors would need to undergo a fusion process in order to be validated and to extract additional features of the system or environment. This creates an interesting opportunity. Since all of the following must be met:

1. the control algorithms of autonomous merchant vessels need to obtain accurate information on the under-keel-clearance to navigate safely especially in shallow, near-shore waters;
2. position of the vessel must be determined with high precision, accuracy and reliability;
3. efficient means of communication between ship and SCC must be ensured

then why can't the collected data be used for the purposes of creating or updating bathymetry of the area?

The concept of the proposed data-exchange system is presented in Fig.4. Herein, bathymetrical data collected by MASS and verified against global-referenced position are transferred to a fleet management centre via a satellite communication link (or any other means of efficient data transfer). Such centre is expected to receive at least periodical reports from MASS for safety reasons [29]. Once cross-checked against revealing potentially confidential commercial information, relevant datasets could be relayed to the relevant hydrographic office in order to update their model of area. If only MASS are not legally restricted to navigate along prescribed routes, vast areas of the sea could soon be covered by a de-centralized fleet of vessels carrying bathymetry sensors. High-density bathymetry charts could be developed using thus created data provided that accuracy standards are maintained on every step of the process.

It shall be noted that an opportunity for such data-exchange did not exist to date. Present-day, conventional ships are usually equipped with one single-beam echo-sounder, satellite navigation systems that not always meet the hydrographic standards [27], [30] and need not to relay environmental data to any party. As a matter of fact, technical capability of transferring any data at high seas with satisfactory rate has only become available in recent years together with the development of commercial satellite communication systems.

Moreover, MASS pre-implementation period appears to be a perfect time for making initial preparations for realizing the said concept. Increased availability of bathymetry data would benefit virtually all actors active in maritime domain, including operators of MASS producing the original datasets. All in all, accuracy and reliability of water depth data affects the process of passage planning – a process that must be carefully performed for autonomous vessels having limited means of in-situ human intervention. Not to mention the fact that corrected nautical charts would be widely published.

In this sense, prospective MASS can be regarded as a de-centralized swarm of hydrographic drones, serving their secondary purpose while fulfilling the primary mission of moving commodities around the world. This will not make the actual hydrographic drones obsolete as there will still be plenty of room at the bottom – in areas that MASS cannot reach due to the draft (shallow waters), or to which their sensors will not be suited (deep waters, for instance). However, near-shore waters, port approaches, straits etc., could be well covered without additional effort or cost except for data storage/transfer and processing.

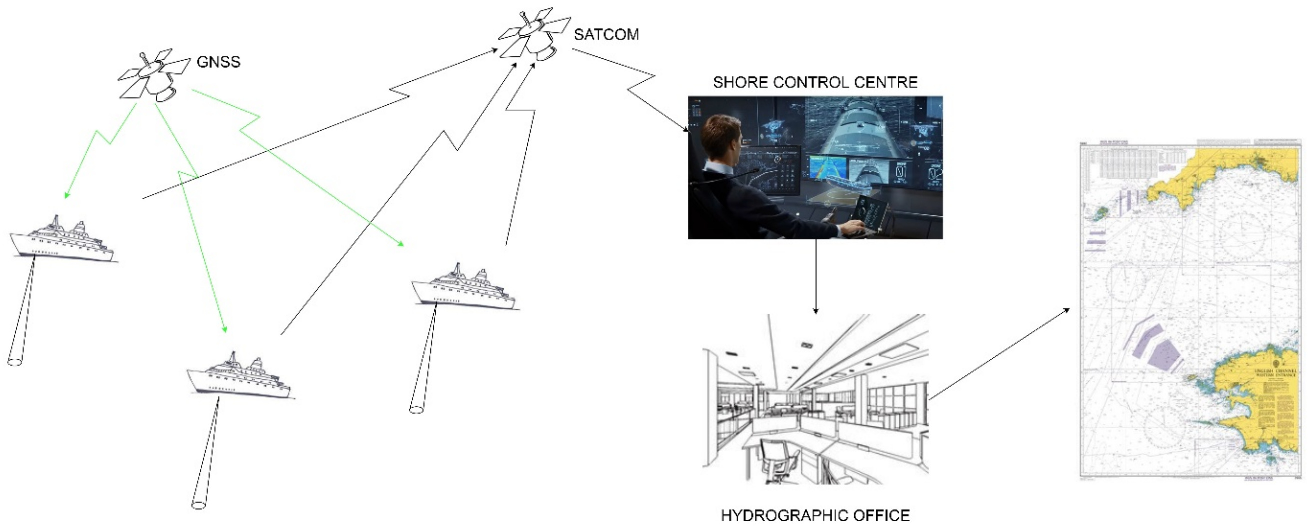

Figure 4. The proposed data-exchange system for de-centralized hydrography

4 SUMMARY

The ongoing digitalisation of the industry did not leave hydrography services or shipping untouched. With emergence of new operational concepts within particular domains, potential for cross-industry, interdisciplinary synergies can be sought to develop new, innovative solutions. To achieve this, at least a means of communication and dissemination between members of different scientific and industrial communities shall be established to identify each other's needs and assets. Within the emergent domain of autonomous merchant shipping, there might exist an opportunity of using therein obtained environmental data to improve safety of navigation.

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REFERENCES:

[1] K. Czachorowski, M. Solesvik, and Y. Kondratenko, "The Application of Blockchain Technology in the Maritime Industry," 2019, pp. 561–577.
[2] H.-C. Burmeister, W. C. Bruhn, Ø. J. Rødseth, and T. Porathe, "Can unmanned ships improve navigational safety?," in Proceedings of the Transport Research Arena, 2014.
[3] K. Wróbel, J. Montewka, and P. Kujala, "Towards the development of a system-theoretic model for safety assessment of autonomous merchant vessels," Reliab. Eng. Syst. Saf., vol. 178, pp. 209–224, 2018.
[4] A.Weintrit, "The Electronic Chart Display and Information System (ECDIS), An Operational Handbook. A Balkema Book, CRC Press, Taylor & Francis Group, 2009.
[5] R. Rylander and Y. Man, "Autonomous safety on vessels - an international overview and trends within the transport sector," 2016.
[6] C. Specht, O. Lewicka, M. Specht, P. Dąbrowski, and P. Burdziakowski, "Methodology for Carrying Out Measurements of the Tombolo Geomorphic Landform Using Unmanned Aerial and Surface Vehicles near Sopot Pier, Poland," J. Mar. Sci. Eng., vol. 8, no. 6, p. 384, May 2020.
[7] L3Harris, "The Autonomous Boat That's Redefining Coastal Hydrographic Survey," 2019. [Online]. Available: https://www.asvglobal.com/the-autonomous-boat-thats-redefining-coastal-hydrographic-survey/. [Accessed: 09-Jun-2020].
[8] Ship Technology, "Rolls-Royce teams up with Google on AI-driven ship awareness," 2018. [Online]. Available: https://www.ship-technology.com/features/rolls-royce-teams-google-ai-driven-ship-awareness/. [Accessed: 09-Jun-2020].
[9] ICRC, "Autonomy, artificial intelligence and robotics: Technical aspects of human control," Geneve, 2019.
[10] Ø. J. Rødseth, "Definition of autonomy levels for merchant ships," 2018.
[11] N. Tesla, "Method of and apparatus for controlling mechanism of moving vessels or vehicles," 613809, 1898.
[12] R. Stokey et al., "AUV Bloopers or Why Murphy Must have been an Optimist: A Practical Look at Achieving Mission Level Reliability in an Autonomous Underwater Vehicle," 11th Int. Symp. Unmanned, Untethered, Submers. Technol. (UUST '99), no. 9970, pp. 32–40, 1999.
[13] V. Bertram, "Autonomous ship technology - smart for sure, unmanned maybe," in Smart Ship Technology, 2016, pp. 5–12.
[14] K. Zwolak et al., "The Autonomous Underwater Vehicle Integrated with the Unmanned Surface Vessel Mapping the Southern Ionian Sea. The Winning Technology Solution of the Shell Ocean Discovery XPRIZE," Remote Sens., vol. 12, no. 8, p. 1344, Apr. 2020.
[15] C. Specht, A. Weintrit, and M. Specht, "Determination of the Territorial Sea Baseline – Aspect of Using Unmanned Hydrographic Vessels," TransNav, Int. J. Mar. Navig. Saf. Sea Transp., vol. 10, no. 4, pp. 649–654, 2016.
[16] Z. Kitowski and R. Soliński, "Application of domestic unmanned surface vessels in the area of internal security and maritime economy - capacities and directions for development," Sci. J. Polish Nav. Acad., vol. 3, no. 206, pp. 67–83, 2016.
[17] K. Kutsuna, H. Ando, T. Nakashima, S. Kuwahara, and S. Nakamura, "NYK's Approach for Autonomous Navigation – Structure of Action Planning System and Demonstration Experiments," J. Phys. Conf. Ser., vol. 1357, p. 012013, Oct. 2019.
[18] C. Kooij, A. P. Colling, and C. L. Benson, "When will autonomous ships arrive? A technological forecasting perspective," in Proceedings of the International Naval Engineering Conference and Exhibition (INEC), 2019, vol. 14, no. October 2018.

[19] H. Ringbom, “Regulating Autonomous Ships—Concepts, Challenges and Precedents,” Ocean Dev. Int. Law, vol. 50, no. 2–3, pp. 141–169, Jul. 2019.
[20] C. Kaminski et al., “12 days under ice - an historic AUV deployment in the Canadian High Arctic,” in 2010 IEEE/OES Autonomous Underwater Vehicles, 2010.
[21] T. Porathe, J. Prison, and Y. Man, “Situation awareness in remote control centres for unmanned ships,” in Human Factors in Ship Design & Operation, 2014.
[22] “Yara Birkeland project paused due to coronavirus,” Maritime Business World, 2020. [Online]. Available: http://www.maritimebusinessworld.com/yara-birkeland-project-paused-due-to-coronavirus-1211h.htm. [Accessed: 09-Jun-2020].
[23] J. Yuh, G. Marani, and D. R. Blidberg, “Applications of marine robotic vehicles,” Intell. Serv. Robot., vol. 4, no. 4, pp. 221–231, Oct. 2011.
[24] N. P. Reddy et al., “Zero-Emission Autonomous Ferries for Urban Water Transport: Cheaper, Cleaner Alternative to Bridges and Manned Vessels,” IEEE Electrif. Mag., vol. 7, no. 4, pp. 32–45, Dec. 2019.
[25] K. Wróbel, J. Montewka, and P. Kujala, “Towards the assessment of potential impact of unmanned vessels on maritime transportation safety,” Reliab. Eng. Syst. Saf., vol. 165, pp. 155–169, 2017.
[26] M. Wahlström, J. Hakulinen, H. Karvonen, and I. Lindborg, “Human Factors Challenges in Unmanned Ship Operations – Insights from Other Domains,” in 6th International Conference on Applied Human Factors and Ergonomics, 2015, vol. 3, pp. 1038–1045.
[27] IHB, IHO Standars for Hydrographic Surveys. Monaco, 2008.
[28] M. Bergström, S. Hirdaris, O. A. V. Banda, P. Kujala, and O. Sormunen, “Towards the unmanned ship code,” in Marine Design XIII, 2018, pp. 881–886.
[29] K. Wróbel, J. Montewka, and P. Kujala, “System-theoretic approach to safety of remotely-controlled merchant vessel,” Ocean Eng., vol. 152, pp. 334–345, 2018.
[30] IMO, Adoption of new and amended performance standards. London: Interantional Maritime Organization, MSC, 1998.