The journey towards autonomous ships and the role of seafarers in the future: a bibliographical perspective

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Abstract

Autonomous ships have become a buzzword in recent years, encouraging technological development on board systems. Many different approaches have been undertaken over the years to figure out how future vessels will look like and whether artificial intelligence (AI) will take over ship operations. There is a need to capture the progress made by the global research community in recent years and highlight trends and developments. This should be done based on an unbiased and in-depth analysis and quantitative evidence. The emphasis of this work is to provide an objective scientometric analysis based on publisher peer-reviewed articles and to contextualise the results against the competencies required for deck officers in the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention. The results show that the digitisation of on-board operations is focused on path planning and tracking, taking collision avoidance rules into account. However, the new concepts and possible systems are not covered by STCW requirements, and future seafarers may be overwhelmed by the new technologies.

Keywords: Autonomous vessel, scientometrics analysis, maritime research trends, STCW Convention

Introduction

The foundation of maritime education and training (MET) is the STCW code that provides a clear framework regarding the competence and the examination process of maritime personnel. The convention, in its major Manila 2010 amendment [1], is based on years of international experience and cooperation and is regularly updated by the Maritime Safety Committee (MSC), which takes the latest developments in the maritime industry into account. The competence catalogue defines the minimum training requirements for a seafarer and provides the institutions of MET with some room for interpretation in the creation of maritime curriculum. Moreover, as recommended from the International Maritime Organisation (IMO), model courses precisely define learning objectives and course structures according to the internationally familiar Bloom's taxonomy [2].

The expected changes by the digitalisation of shipping will have an impact on a seafarer's job description, with the focus on human-automation collaboration and shore-based ship operation [3–6]. It is the role of an MET institution to initiate progress and ensure the employability of future maritime professionals, whether it is the case of vocational training or the academic path.

There are a large number of literature reviews addressing autonomous shipping; however, to best of our knowledge, they do no attempt to cover the bigger picture and rather focus on a specific area, for instance, decision support systems [7], artificial intelligence [8], business models [9] and seafarer training needs [10]. Therefore, main objectives of this article are (1) to map out the main areas where progress is being made, (2) to contribute to the scientific debate and quantify research efforts and (3) to draw conclusions on the role of seafarers in the future based on progress made in key areas.

A bibliometrics research, as defined by Prithard [11], is “application of mathematical and statistical methods” for dealing with recorded values. The analysis is based on the co-occurrence of distributions and bibliographic coupling derived from data such as keywords, citations and references of the extracted research publications. Emphasis is placed on bibliometric coupling to define the main underlying topics of future automation and recent development. The results of the analysis stretch to a holistic view of future seafarers’ future competencies and skills as a step to evaluate the conformity of the STCW code. The scope considers newly evolving shore-based professions and possible adaptive positions for personnel with seafaring experience.

Research Methods

For the purpose of this study, data was obtained from Web of Science (WOS) on the 1st of January 2021. It is one of the major bibliometric databases [12]; inclusion of other catalogues was considered but discarded due to comparability and stability of the statistics obtained from different sources, for instance, abbreviation of sources, categories and number of citations. By using the search terms listed below in the title, abstract and keyword, the query was kept straightforward while allowing for a very broad search. Associated additional terms such as Shore Control Center (SCC) and Shipping 4.0 were not included, as an initial query revealed that articles directly related to autonomous shipping contain some of the terms in the abstract, title or keyword, which are expanded by additional terms not included in the search query.

TITLE-ABS-KEY (autonomous AND vessel OR autonomous AND shipping OR autonomous AND ship* OR unmanned AND ship* OR unmanned AND vessel*)*

Data cleaning is divided into two parts, as shown in Figure 1. Based on the general wording of the query in the first stage, we evidently removed unrelated research areas, languages other than English and entries based on keywords in the title. Thus, peer-reviewed publications in English that were directly related to autonomous ships and published between 1990 and 2020 were filtered. This was done by a semi-automatic script (i.e., rows were removed based on predefined criteria). In the second part, the results of the included and excluded articles were verified by the authors, a further reduction based on the article abstracts.

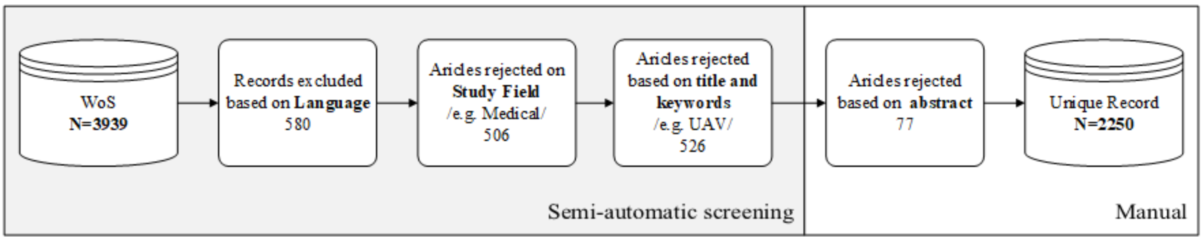

Figure 1. Data pre-processing steps showing the total number of included and excluded articles

The raw data were processed in bibliographic software: (1) BiblioTool 3.2, for the creation bibliometric maps [13], and (2) ScientoPy, for a scientometric analysis [14]. As described below, bibliographic coupling is based on the similarities in the references/links shared by any two articles. This does not provide a direct view of trend development, whereas a frequency-time distribution, as proposed by Ruiz-Rosero et al. [14], offers a measurable result derived from relative and absolute growth indicators. Both tools have been proven in numerous large-scale studies on bibliometric analysis [15]–[18]. Hence, this research firstly exhibits a sequential analysis to identify trending topics based on growth indicators, and secondly, it presents a science map to describe the structure in the field of autonomous shipping, whereby we use the results to interpret the future competencies for virtual seafarers.

In the “Results” section, initially, we present an analysis of the bibliometric variables based on all 2250 publications, which provide information on:

- Country and institute frequency: to define the main contributors in this field

- Average growth rate (AGR), average documents per year (ADY) and percentage of documents in last years (PDLY) as indicators for topics that gained momentum in the past years

AGR (Eq.1), ADY (Eq.2) and PDLY (Eq.3) are the indicators required to estimate the relative and absolute growth of an item within the corpus, where, for the temporal analysis, the user defines start(Y_s) and end(Y_e) years that are compared to the numbers of documents per year(P_i) or in relation to the total numbers of documents (TND). Ruiz-Rosero et al. [14] apply the following reckonings methods:

$$AGR = \frac{\sum_{i=Y_s}^{Y_e} P_i - P_{i-1}}{(Y_e - Y_s) + 1} (1) \quad ADY = \frac{\sum_{i=Y_s}^{Y_e} P_i}{(Y_e - Y_s) + 1} (2) \quad PDLY = \frac{\sum_{i=Y_s}^{Y_e} P_i}{(Y_e - Y_s + 1) * TND} (3)$$

The development of the concept of autonomous vessel has gained momentum in the last decade. We, therefore, further considered bibliographic coupling to be convenient; its main advantage is that it can detect even weak signals (new articles without citations) [13], [19], [20]. As Equation 4 shows, a bibliographic link between two publications is created if they jointly cite a third (it all depends on which publications are in the bibliography of the articles). In this respect, clusters are formed based on the similarity of the article citations, according to Kessler's [21] omega value, defined as shared references ($R_i \cap R_j$), divided by the square root of the product of all references (Eq. 4). Therefore, the more common references two articles have, the higher the omega value and the more likely they are to be placed in the same cluster.

$$\omega_{i,j} = \frac{|R_i \cap R_j|}{\sqrt{|R_i| \times |R_j|}} (4) \qquad \sigma = \sqrt{N} \frac{f - f_0}{\sqrt{f_0(1 - f_0)}} (5)$$

The omega similarity value quantifies the relationship between the articles, as it expresses the link weight between two objects. Grauwin [13] adopts the Louvain algorithm to find partitions based on the Newman-Girvan modularity function, which is widely used to detect communities in a complex system. The algorithm is using a greedy optimisation for identifying the maxima of modularity, which is further enhanced by a hierarchical refinement [22]. Roughly, it indicates the density of links (in our case references) within communities in a ratio to the total number of edges in the corpus, expressed as a scalar value between -1 and 1 [23]. As suggested by Grauwin [13], the characterisation of the communities can be indicated based on the significativity (σ) of an item, by comparing the frequency distribution of an item (f) in the cluster to the overall item frequency in the corpus (f_0), normalised as shown in Equation 5.

Results

A total of 2,250 articles related to autonomous shipping were identified, where we count autonomous underwater vehicles (AUV), autonomous survey equipment or, in fact, just about any autonomous floating object related publications. Consequently, the top 10 countries and academic institutions in the corpus are shown in Figure 3 and Figure 4. Some inferences on the curiosity of autonomous shipping, especially in China, Norway and Poland, are clearly visible. These countries have published more than 40% of the articles included in the corpus since 2019 on this topic than in previous years.

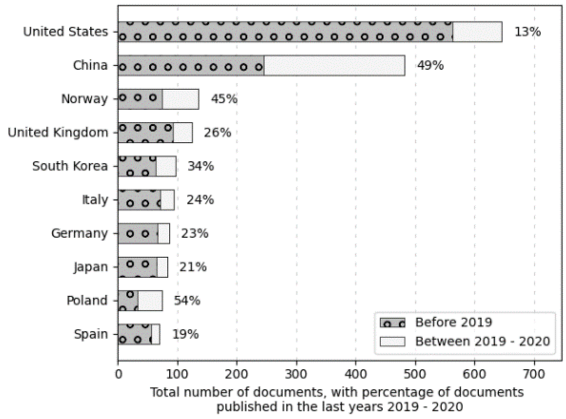

Figure 3. Top 10 contributing countries compared to the percentage publish article since 2019

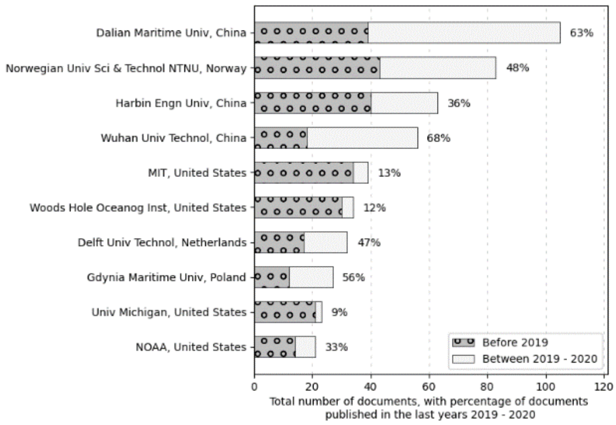

Figure 2. Top 10 contributing institutions in relation to the percentage of documents published since 2019

The detection of trending topics shown in Table 1 are based on authors' keywords, where we have identified the top 10 topics using the indicator $PDLY$ greater than 60% and AGR greater than 2. The excluded keywords are *SHIP*, *VESSEL*, *SYSTEM* because they do not convey a direct indication.

Table 1. Trending topic according to the absolute and relative indicators

Author's Keyword	N	AGR	ADY	$PDLY$
collision avoidance	65	7.5	19	58.5
neural network	41	2.5	11	53.7
sliding mode control	27	2.5	9	66.7
MASS	17	4.5	8.5	100
input saturation	14	3	6	85.7
Uncertainty	13	2.5	5	76.9
Maritime safety	9	2	3.5	77.8
Deep reinforcement learning	8	2	4	100
Trajectory	7	2.5	3	85.7
Heuristic algorithm	6	3	3	100

With the aim of understanding the structure of a research subject more efficiently, we applied cut-off points to select the most interconnected, in this sense, representative articles. The bibliometric-coupling network is constructed by connecting pairs of publications that share at least 3 references and exhibit greater than 0.050 Kessler similarity. From the dataset of 2,250 publications and 54,374 references in total, we were able to find 985 publications that met the criteria. Further defined is that a main cluster should consist of at least 25 publications and the sub-clusters should consist of at least 5 publications. Based on these criteria, the Louvain algorithm categorises 7 main clusters and 37 sub-clusters. In this article, the main clusters are presented, while a comprehensive and interactive summary of the results can be found at https://maritime-research.gitlab.io/iamu/. Henceforth, the corresponding network structure for the remaining corpus is: average links (k) of 13.46, the density of links $(d = 2k/(N-1))$ of 0.027 and the internal modularity(Q_i) of 0.626 for the corpus. Additionally, the average publication year (PY) and the average age of the references in the cluster (A_{ref}) provide information about the freshness of a cluster. Table 2 delivers a summary of the statistical results.

Table 2. Quantitative characteristics of the top 7 clusters

Main Clusters	N	k	d	$\omega_{in} * 10^{-3}$	Q_i	PY	A_{ref}
All	*985*	*13.46*	*0.027*	*0.857*	*0.626*	*2015.42*	*8.59*
Collision Avoidance	171	10.56	0.124	7.382	0.428	2017.56	9.02
Neural Network	129	25.41	0.397	23.153	0.248	2018.21	6.63
Tracking Control	109	15.85	0.294	24.885	0.322	2012.29	9.64
STPA	69	9.91	0.292	13.978	0.280	2018.64	7.48
Path Following	58	17.86	0.627	43.895	0.251	2017.50	7.40
Visual Inspection	57	6.11	0.218	17.243	0.536	2013.04	8.99
Object Detection	47	4.47	0.194	14.268	0.489	2018.40	7.80

Furthermore, Figure 5 offers a graphical representation that provides a thematic overview of the connectedness between the clusters (edges). The central role in the corpus is taken by the "Collision Avoidance" cluster and its connection between all clusters. It can be reasoned that the "Collision Avoidance" cluster may be regarded as the most influential in terms of connectivity and essential for the progress in autonomous shipping. In addition, the "Path Following", "Neural Network" and "Tracking Control" clusters have stronger interconnectivity (shared references) compared to the other clusters. "Visual Inspection" is more remote and shows minimal connectivity to the other clusters.

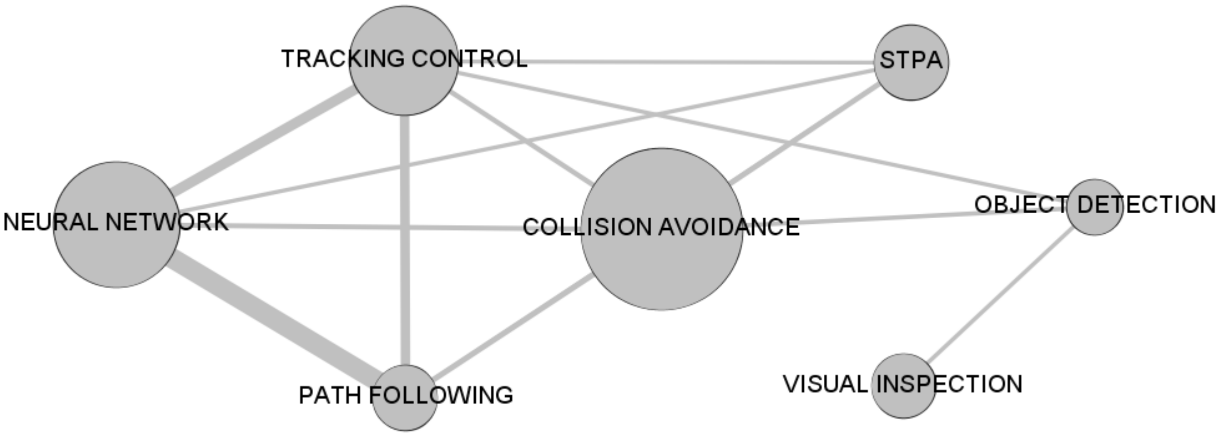

Figure 4 Main clusters identified in the corpus, where the circles are proportional to the size and edge thickness proportional to the similarity of two topics

"STPA" and "Object Detection" are connected to the largest cluster but have low connectivity to the other clusters. However, they can be considered as new areas of exploration in terms of both size and average publication age.

The largest cluster dealing with autonomous operation includes 171 publications. Based on the most significant keywords, namely *COLLISION-AVOIDANCE* ($\sigma = 10.73$), *COLREGS* ($\sigma = 9.44$) and *PATH PLANNING* ($\sigma = 8.36$), the research focus within the cluster lies in providing suitable options for adaption of the collision avoidance rules in autonomous shipping. The People's Republic of China is represented within the cluster with a participation of 38.01% and significancy of 5.01, followed by the USA, represented with 13.45% participation and significancy of -4.77, indicating that the country is more active in other clusters; Norway and UK present 11.70% participation and significance of 2.88 and 3.20, respectively. Table 3 exhibits the five most representative articles for the clusters, where in-degree (d_{in}) represents the number of publications in the cluster that are linked to the article. Therefore, researchers are actively working to define sustainable solutions for target tracking and motion prediction, collision detection and risk evaluation of alternative paths, and conflict resolution, to execute a collision-free solution [24].

The second largest group, "Neural Network", consists of 129 publications. The most active countries are the People's Republic of China with 83.72% participation with significancy of 16.89, followed by Australia with 6.20% and 2.34, USA with 5.43% and -6.13 and Iran with 3.88% and 4.84. In this cluster, we identified five sub-clusters with most significant keywords as extended state observer, trajectory tracking, formation, prescribed performance and dynamic surface control. The cluster shows some similarities with the first cluster in terms of keyword and research direction, but articles are more focused in trajectory tracking, AUV and coordinated path tracking of multiple autonomous vessels. It is noteworthy that the bibliographic linkage is based on the similarities of references and the dominance of one country that may form an independent cluster, as researchers are more familiar with past research from their home country.

The third largest cluster identified in the corpus, "Tracking Control", consists of 109 publications. The most significant keywords are: *BACKSTEPPING* ($\sigma = 5.96$), *UNDERACTUATED SYSTEM* ($\sigma = 5.81$) and *TRAJECTORY TRACKING* ($\sigma = 4.30$). The most represented countries in this cluster are the United States with 36.70% participation at a measured significance of 1.48, followed by the People's Republic of China with 33.03% participation at a significance of 2.75 and Canada with 11.01% participation at a significance of 4.93. The research interest within the cluster is mainly focused in motion controls such as cascade control, backstepping, sliding mode and parameter estimation. The researchers' proposals go beyond the Nomoto model introduced in 1957 [25], which is commonly incorporated into technical navigation curricula. The average publication year for the cluster is 2012, which can be seen as the birth of advance control and automation ideas.

The fourth cluster, in the evaluation identified *STPA* as the most significant keyword, followed by *STAMP* ($\sigma = 8.60$) and *SAFETY OF TRANSPORTATION* ($\sigma = 7.44$). In this cluster, Gdynia Maritime University, Aalto University and Norwegian University of Science and Technology NTNU are the main contributors to the safety evaluation of the new technologies. At the country level, it is Norway with 30.43% at a significance of 8.22, Finland with 18.84% at a significance of 10.53, China with 18.84% at a significance of -0.65, followed by Poland with 17.39% at significance of 6.36. Research efforts are focused on evaluating safety issues related to the adaptation of autonomous technologies and human-autonomy collaboration. Besides, the articles are offering view on possible human or software failure.

The fifth cluster, "Path Following", contains 58 articles that address challenges related to taking path control and following it. The cluster is similar to "Tracking Control" and explores further scenarios, such as model predictive and adaptive controls. Further, a comparison between the average publication year of the group in 2012 and 2017 shows that this is a newly formed group in which more hypotheses and propositions are explored. The emphasis here is on the practical application of the line of sight

(LOS), control law and exposure to various parameter uncertainties and unknown time-varying external disturbances. It is predominated by China, which contributes 70.69% of all articles with measured significance of 8.92, followed by Norway with 15.52% and significance of 2.87 and Portugal with 10.34% and significance of 3.86.

The cluster "Visual Inspection" focuses on acoustic navigation, localisation and autonomous research sensors for oceanography or archaeology. The next most representative keywords are: *SENSOR COVERAGE* ($\sigma = 8.26$), *VISUAL MAPPING & SLAM* ($\sigma = 6.74$) and *INFORMATION GAIN* ($\sigma = 6.74$). The following countries are more active in the cluster: USA with 66.67% participation and significance of 6.00, Australia with 14.04% participation and significance of 5.14 and South Korea with 12.28% participation and significance of 2.84. As shown in Table 2, the average publication year for the group is 2013, and it is not strongly connected to the other clusters. However, certain parts of the research are relevant to autonomous vessel, for instance, relative positioning such as long-baseline (LBL) systems, motion reference unit (MRU), visual simultaneous localisation and mapping (SLAM), sonars and photometric. In terms, the cluster relates to AUV and survey methods, which, in the past, proved to be probably the most valuable entry points of autonomous maritime technology, as such works tend to be labour intensive, repetitive and operational cost are high. The use of those sensors is currently not covered by the mandatory part of STCW but in the external offshore industry-recognised learning route for dynamic positioning operator (DPO).

The cluster "Object Detection" has 47 publications. The most significant key words are related to image processing and shapes. The leading contributing countries in this field are China with 36.17% and a significance of 2.32, followed by South Korea with 19.15% and a significance of 4.85 and Norway with 14.89% and significance at 2.41. The cluster is in relation to the other cluster "relatively new" ($PY = 2018.40$) and has publications that mainly describe methods for image processing and ship detection in terms of multi-sensor fusion and deep learning (image classification). Moreover, it is the cluster aiming to cover the requirements of lookout in satisfaction of the current international legislation. Here, we have the case of technology that is not covered by the STCW standards.

Table 3. Most representative publications in the clusters

Main Clusters	d_{in}	Times Cited	Publication Ref
Collision Avoidance *(N = 171)*	79	22	Huang YM, 2020, SAFETY SCI (121) [24]
	50	2	Guardeno R, 2020, J MAR SCI ENG(8) [26]
	47	24	Polvara R, 2018, J NAVIGATION(71) [27]
	46	0	Huang YM, 2019, OCEAN ENG(173) [28]
	43	22	Singh Y, 2018, OCEAN ENG(169) [29]
Neural Network *(N = 129)*	78	2	Peng ZH, 2019, OCEAN ENG(191) [30]
	67	16	Liu L, 2019, OCEAN ENG(171) [31]
	65	17	Liu L, 2019, IEEE T NEUR NET LEAR(30) [32]
	64	0	Liu L, 2020, OCEAN ENG(209)
	62	16	Peng ZH, 2018, IEEE T CONTR SYST T(26) [33]
Tracking Control	69	192	Liu ZX, 2016, ANNU REV CONTROL(41) [34]
	69	51	Ashrauon H, 2010, P AMER CONTR CONF() [35]

(N = 109)	59	109	Yu R, 2012, IET CONTROL THEORY A(6) [36]
	54	2	Kim K, 2013, MED C CONTR AUTOMAT() [37]
	51	4	Ashra uon H, 2015, P AMER CONTR CONF() [38]
STPA	40	4	Fan CL, 2020, OCEAN ENG(202) [39]
(N = 69)	33	1	Wrobel K, 2020, SAFETY SCI(129) [40]
	28	6	Zhang MY, 2020, SAFETY SCI(130) [41]
	27	0	Ventikos NP, 2020, SAFETY SCI(131) [42]
	25	32	Wrobel K, 2018, OCEAN ENG(152) System [43]
Path Following	38	6	Xu HT, 2019, OCEAN ENG(194) [44]
(N = 58)	38	1	Li MC, 2019, IEEE ACCESS(7) [45]
	37	0	Xu HT, 2020, EUR J CONTROL(53) [46]
	35	1	Wan LL, 2020, OCEAN ENG(205) [47]
	35	0	Yao XL, 2020, NEURAL COMPUT APPL(32) [48]
Visual Inspection	24	116	Hover FS, 2012, INT J ROBOT RES(31) [49]
	21	3	Hong S, 2019, J FIELD ROBOT(36) [50]
(N = 57)	19	97	Kim A, 2013, IEEE T ROBOT(29) [51]
	16	31	Johnson-Roberson M, 2017, J FIELD ROBOT(34)
	11	13	Ozog P, 2013, IEEE INT C INT ROBOT() [52]
Object Detection	15	1	Huang ZJ, 2020, COMPLEXITY (2020) [53]
	15	0	Lin W, 2019, LECT NOTES ARTIF INT(11741) [54]
(N = 47)	10	12	Farahnakian F, 2020, REMOTE SENS-BASEL(12) [55]
	10	0	Han J, 2020, J FIELD ROBOT(37) [56]
	9	1	Chen ZJ, 2020, SAFETY SCI(130) [57]

When it comes to making sense of the outcomes of above clusters from the educational perspective and the role of future seafarers, there are some significant areas to mention:

- The trending topics in Table 1 suggest that the research focuses on components of automation, such as machine learning, system identification and safety and collision avoidance solutions. Although the STCW code states the paramount importance of safety and collision avoidance, systems theory or machine learning are foreign words for the code and navigators. Yet, competences of understanding these concepts seem relevant, not only for a future of automated vessel environment but also in understanding today's bridge systems.
- The largest cluster "Collision Avoidance" shows that main focus is put on collision avoidance in autonomous systems through tracking, detection, risk assessment of the alternatives and execution of all interconnected actions. The results of all these actions do heavily depend on

commercially available sensors in conjunction with on-board computers. Most importantly, it includes limitations and strong assumptions, such as limitation of the scenarios, constant velocity of the target and simplification of the ship dynamics [27], [55]. This triggers the development of ship motion models, probability risk estimators and fuzzy methods among many other design elements. The STCW code requires navigators to have *"Thorough knowledge of content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended"* [1] *(STCW* - A-II/2 and A-II/3 for Watchkeeping). Clearly, the future requires more than this, as we are talking about a level of autonomy where the officers are present onboard, but most of the operations are being conducted autonomously, in an environment where there is a remote operator involved in the operation whenever it is deemed necessary. It remains unclear, for the moment, to what extent an officer onboard or an operator in a remote control centre (RCC) must be familiar with the operation principles of the above-mentioned systems.

- The cluster "Path Following" shows the focus of more complex path tracking and makes it clear that, for example, the steering control goes beyond the standard autopilot setup, such as with a proportional-integral-derivative (PID) controller (STCW Table AII-3).
- The "Visual Inspection" cluster refers to *"ability to operate safely and determine the ship position by use of all navigational aids and equipment commonly fitted on board the ships"* (STCW A-II/3); however, the term *'commonly fitted equipment'* seems to become obsolete.
- When it comes to the cluster of "Object Detection", we talk about a technology that is not covered by the STCW code. It is worth mentioning that this cluster aims at covering the requirements of lookout to satisfy the current international legislation.

In summary, the results show that certain areas of good seamanship such as path planning (voyage planning), path tracking (voyage monitoring) and collision avoidance are covered by research articles. Most importantly, the necessary onboard sensors and systems for autonomous or highly automated operations are not within the scope of the mandatory STCW standards. In recent years, newly developed methods for risk assessment have been proposed, with an overview on potential hazards regarding human-machine interactions. Although studies indicate that personnel on board or ashore need to be trained accordingly, and the tasks of SCC are considered from many angles, it remains unclear which skills need to be trained internationally and to what extent. To our knowledge, few publications address the integration of new technologies into MET and provide initial assessments of potential overall improvement [58]–[67]. A clear conclusion from these studies is that the future challenges for seafarers are to have the traditional seafaring knowledge, but also to be flexible and constantly adapt to new technologies through lifelong learning. Emad et al. [67] point out that "…the availability of qualified lecturers who are able to provide the required training" is another issue and that MET institutions need to strengthen their human resource strategy.

In this paper, we used 2,250 articles for evaluating the research effort and created a bibliographical map of most interconnected articles. Based on the results, we found many areas of STCW competences without coverage: provide medical care on board, handling emergency situations, leadership and managerial skills, monitor and control compliance with legislative requirements, control stability and stress, asses reported defects, plan and ensure safe loading, stowage and securing of cargo, and coordinate search and rescue (Table A-II/2). Thus, one of the questions arising is how the manning of a vessel can be reduced or a vessel can be remotely controlled, by ensuring the complete coverage of the current vessel operation requirements. Therefore, we consider that the education of seafarers and the occupation itself will remain relevant for the future. Nevertheless, the concept of the education needs to be more dynamic; the mindset of the seafarers needs to adapt to this dynamic environment.

The objective of this paper is to spot challenges faced by maritime training institutions in preparing seafarers of the future. As highlighted by Sharma [59], the advent of new technologies brings the need to educate seafarers with new technical and non-technical skills. Our study confirms that a large portion of technological development is not being covered, and seafarers may be overwhelmed when trying to understanding the new technologies. It is becoming clear that courses such as maritime data science, where the term itself implies an undergraduate education in mathematics, probability, statistics, machine learning and programming skills, may become an essential part of future maritime operations and one of the prerequisites for serving as an operator onboard or ashore. In this sense, advanced education in computer science and its integration into current maritime education standards may not be possible, particularly in vocational training.

Understanding the principles of technology and components of the system is one side of the coin; the other side is gathering the cognitive skills to be able to not only apply, analyse and evaluate the decisions made by a machine but also to question these decisions. Overreliance on technical equipment has been and still is a major issue within ship operations, and has been proven by numerous accident investigation reports [68]. Seafarers already tend to be overwhelmed by the existing technology. A good and recent example to this is the introduction of the electronic chart display and information system (ECDIS) onboard and the evolvement of the same technology to this date. At the very beginning, there were serious issues with design and user-friendliness. This is showing a positive trend recently; however, accident reports still recognise wrong ECDIS settings or untouched settings for months. Therefore, the partly neglected research subjects—human-machine interaction in a more automated-environment, adaptation to technologies and creating a true understanding of what technology does and what it does not—seem to be the key issues to explore further.

Conclusions and Limitations

One of the limitations and, at the same time, strength of the study is the use of exclusively scientific literature, where the projects, such as newly adopted test field, regulatory changes, ready to use equipment and system from manufacturers, are not considered. Another limitation is that bibliographic cross-linking between multiple databases is impractical for credible analysis of article references, and in this work only the largest identified dataset on autonomous shipping, namely WoS, was used.

The results show the known facts about how interest in the topic is growing and maritime institutions have become very active in research in the recent years. The focus of the research in the field still lies in path planning and following it. Wróbel et al. [40] note that the vast majority of research focuses on the technical aspects and that other aspects such as social, legal or organisational factors are still characterised by uncertainty, which is, once again, confirmed by this study.

The systematic approach in this paper allowed us to convey the results into discussions of the possible need for change in a seafarer's job description and emerging competencies. The sustainable future as a profession and how the rapid technological development will affect the future of the maritime professions and, therefore, MET were pointed out. Many maritime universities are providing the education at bachelor's level that ensures a level of content beyond the minimum requirements set by the STCW. It is worth reviewing the scope of the curriculum as early as possible to take steps towards preparing seafarers for a more complex environment, no matter how unclear certain parts of the development with regards to technology, legislation and organisation are.

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