eMaritime Integrated Reference Platform

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Abstract: *Driven by German industry in the context of the NMMT, the eMaritime Integrated Reference Platform eMIR provides an open modular research and test environment used for scientific analysis of maritime systems, for R&D by providing testbeds for validation and verification, for demonstration and evaluation of new maritime technologies in navigation, organization and surveillance or maritime (transportation) systems. Actually, it includes virtual and physical testbeds provided by OFFIS and DLR.*

Following a joint interoperability architecture, eMIR provides the basis for the implementation and integration of testbeds as well as project outcomes and to provide a sustainable opportunity to present project outcomes, products and services.

1. Introduction

The maritime sector plays a key role within every agenda for future global mobility. By the increasing establishment of ICT-based components, such as bridge elements and automation technology, a radical change similar to the mobility on land and the aircraft industry can be observed, e. g. unmanned surface vehicles (USV) or autonomous surface vehicles (ASV) can be found of future technology roadmaps. Harmonized strategies for e-navigation system design (e. g. the e-navigation Strategy Implementation Plan (SIP) by IMO) and safety requirements change the shipping industry in political and technological ways since several years. [3] reports that more than 75 percent of all worldwide naval accidents are caused by human factors. Next to the safety argumentation, governmental sustainability plans such as the Paris Agreement, which has been signed by 195 countries at the time of June 2016, establish universal bindings for a global climate deal to reduce emissions [8]. To achieve these aims, intelligent transport systems are needed that increase the safety and efficiency, e. g. route optimisation under consideration of the environmental context. There is evidence of a trend towards getting highly automated vessel assistance systems with an outlook for the future describing autonomous seafaring.

A number of testbeds for new e-Navigation and surveillance technologies are under design and implementation around the globe. These testbeds have numerous objectives: Understanding challenges and requirements for e-Navigation, the development and test (validation and verification) of platforms or for the demonstration of the maturity of new technologies.

The international organizations that foster-Navigation like IALA and IMO as well as national bodies regard testbeds as an important method to invent and develop new e-Navigation concepts and technologies as well as their dissemination and exploitation. Testbeds could also provide fruitful information about the maturity and usefulness of new standards and specifications (like S-100ff).

Driven by German industry in the context of the National Masterplan for Maritime Technologies NMMT, eMIR provides an open modular research and test environment used for scientific analysis of maritime systems, for R&D by providing testbeds for validation and verification and for demonstration and evaluation of new maritime technologies for navigation, organization and surveillance or maritime (transportation) systems. Actually, it includes virtual and physical testbeds provided by OFFIS and DLR.

Following a joint interoperability architecture, eMIR provides the basis for the implementation and integration of testbeds as well as project outcomes and to provide a sustainable opportunity to present project outcomes, products and services. The communication infrastructure is currently as a modified high-level architecture (HLA) implementation for the simulation environment combined with a message passing middleware for the physical testbed. This infrastructure allows the communication between different simulation components in a co-simulation environment but also the communication between developed software and physical testbed systems.

eMIR allows the early testing of new maritime technologies in a complex simulation environment and the seamless transfer of these technologies into a physical testbed. The basis of the architecture is a communication infrastructure, a common semantically defined world data model and a polymorphic integration interface.

The testbeds cover the virtual testbed Hybrid Architecture for Granularly, Generic and Interoperable Simulations (HAGGIS) for simulation based V+V, the physical testbed LABSKAUS (German: LABor für SicherheitsKritische Analysen aUf See / English: LABoratory for Safety Critical Analysis On Sea) and the Research Port Rostock Warnemünde. They contain:

- Reference Waterway with communication and surveillance technology along the Elbe between Cuxhaven and Brunsbüttel
- Research Port Rostock Warnemünde: Testbed for safety and security technology with special focus on the development and testing of applications as well as technologies based on Global Navigation Satellite Systems (GNSS)
- Mobile Bridge and experimental Vessel Traffic Services System: For experiments in situ or in a simulation environment
- Traffic Database for data analysis and scenario
- Research Boats like Otzum and Zuse: Experimental platforms located in Wilhelmshaven.
- Maritime Traffic Simulation: Providing test scenarios
- Environmental Simulation: To generate wind, current, wave, tidal influenced simulation environment
- Sensor Data Simulation: To generate test data for technical systems under validation/verification

For the integration of prototypes into the cyber-physical testbed, we present a testbed architecture which focuses on the needs of enterprises and stakeholders by a process-oriented design approach containing a polymorphic interface.

2. Maritime Testbeds and Platforms

New technologies can be tested by simulations and in-situ. Simulators can be used for simulating real life conditions for users like bridge simulators found around the world or big scaled environment planning/control algorithms like the Maritime Traffic Simulator [19]. But to prove the concept for real-life applications, a prototype has to show its functionality within a real environment.

Maritime Testbeds are used for prototypes of e-Navigation technologies. A lot of maritime projects developed testbeds to test specific technologies, e. g. the North Sea (ACCSEAS [11]), Baltic Sea (EfficienSea [12] [13], Mona Lisa [14]), Adriatic (ARIADNA [17]), Ionian Sea (IONO [16]), straits of Malacca (SESAME Straits [18]) and Japan (SSAP [15]). These testbeds are specialized by their individual use-cases. Most of them want to improve planning and coordination of ship movements and increase safety on sea. An important role is the exchange of information to be able to create new features and derive improved functionality for every testbed on sea.

Generic testbed platforms are another approach for testing new technologies: reusable and configurable. This approach adopts concepts from the automotive industry like the Application platform for Intelligent Mobility (AIM). AIM is a component-based testbed for land traffic [20]. It has mobile components like a car fleet or structural components like a research crossway, research railway crossing or reference way Car2X. It also offers driving or virtual reality simulators. These components are test carrier for new technologies. The data gathered can be used later for simulations or other research. If a new traffic observation or management requires a testbed it can be implemented in the AIM testbed. The virtual reality laboratory is built around a modular mock-up car which allows integration of new driving assistant systems, that they can be evaluated in a static environment. The target of AIM is to be a versatile test environment for broad diversity of land transportations technologies. This paper describes how such an approach can be brought to the maritime domain.

4. Integrated Testbed

An open maritime testbed for new e-Navigation technologies will bring technologies of the maritime domain faster forward. Helping the development process with accessible and component based test environments that are obstruction free as possible is the aim of eMIR [26]. Open testbed means that eMIR is open to integrate new technologies, demonstrations or sub platforms. For interoperability and to implement shared services, eMIR provides a shared infrastructure and interoperability architecture as described in the following chapter. In this nation wide industrial approach for maritime system engineering three testbeds are integrated:

HAGGIS is a modelling and open co-simulation environment to build virtual e-Navigation testbeds and part of eMIR. It enables rapid testing of new e-Navigation technologies in a simulation environment. HAGGIS consists of a number of modules that can be orchestrated for different applications. These allow simulating Maritime Traffic, Sensors, Environments, and human behaviour.

Research Port Rostock/Warnemünde as a testbed for Position, Navigation and Timing experiments with a special focus on GNSS. Particular attention is paid to maritime utilization concepts for the European Satellite Navigation System Galileo. With the terrestrial Pseudolite-system "Sea Gate" and a maritime Ground Based Augmentation System (MGBAS) for the assessment of GNSS based data, two systems are forming the basis for the acquisition and processing of GNSS signals. The Maritime Simulation Centre Warnemünde (MSCW) completes the research infrastructure in the way that it combines different simulation facilities of realistic scenarios for ship handling and the prediction of manoeuvres using data of Sea Gate or MGBAS and the evaluation of those.

The Sea Gate system consists of nine Pseudolites (PSL - Pseudo Satellites, see Figure 3). Each PSL performs in the same way as a GNSS satellite but with the important difference that the system is ground based and the signals are pulsed. All PSL sends signals according to [3] at E1 (1575,42 MHz) und E5 (1191,975 MHz). The area of operations is around 20 square kilometres. The system allows the hybrid utilization of real GNSS signals (GPS, GLONAS, Galileo) together with the pseudolite based signals. The available horizontal accuracy in standard mode is 4 m (2 σ). By using differential corrections of the reference stations the horizontal accuracy can be improved to around 0.2 m.

Figure 1. Installation of the signal generators (yellow) and dedicated reference station (red) as part of the Sea Gate system in the vicinity of the overseas port Rostock

The MGBAS was installed to observe the Port of Rostock concerning intended or unintended signal interferences. Beside the provision of correction signals and parameter, the core element is an integrity monitoring for all GNSS and DGNSS (differential modes as for example IALA Beacon DGNSS). Based on the degree of disturbances an RTCM based integrity message can distributes to exclude specific satellites from positioning or declare a whole service as “not applicable” under consideration of the requirements on accuracy and integrity.
Concerning operational aspects, the MGBAS supports applications covering positioning, navigation, and time information as well as applications in the direction of vessel tracking and situation awareness. The two examples in Figure *2* represent two systems for a reliable provision of navigation relevant parameter and data [4][5].

Figure 2. Left: Monitoring of Position, Navigation and Time data as part of a PNT-Unit; Right: AIS Real-time plausibility monitor

The **LABSKAUS** testbed is the physical part of eMIR and is placed in the German Bight. Even though some components are transportable and can be located everywhere. In the following paragraphs all existing components will be described.

Reference Waterway

The Reference Waterway covers the Elbe and Kiel Canal Approach near Brunsbüttel and Elbe estuary around Cuxhaven Germany. It covers a basic maritime surveillance infrastructure (including AIS, Radar, cameras) and broad band communication via LTE e.g. Figure 3. On the left side of Figure 4, Radar and AIS Tracks gathered from Cuxhaven are visualized.

Figure 3. Left: Sensorpole Cuxhaven, right: sensor pole and Navibox Brunsbüttel

It can be individually expanded with the autarky stations. This setup is used as an experimental platform for demonstration of new technologies the source for a database with travel patterns and near collisions. Additionally, two AIS Receiver are connected to two Antennas atop a building north of Wilhelmshaven. With good condition they can cover Wilhelmshaven, Bremerhaven till Cuxhaven and East Frisian Isles till Helgoland to enhance the Reference Waterway. In the right side of Figure 4 the range of AIS targets from the LABSKAUS infrastructure is shown.

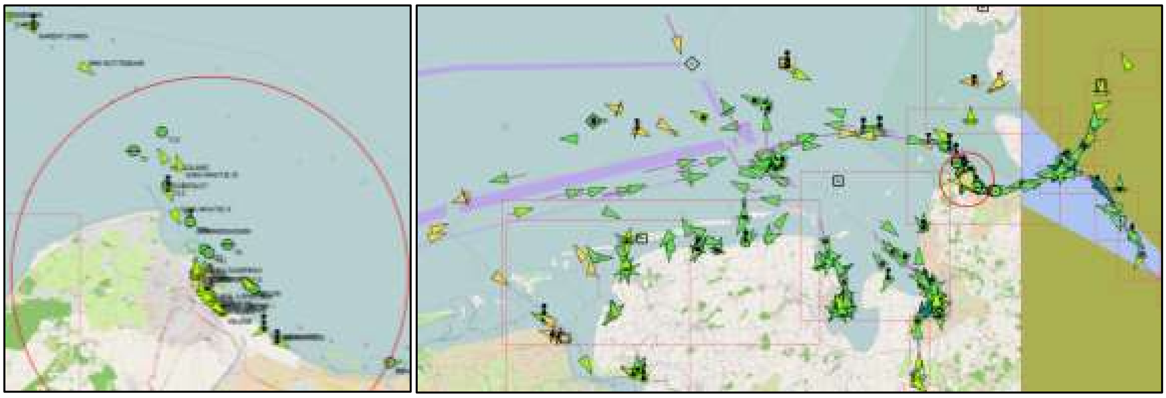

Figure 4. Left: Screenshot of Radar and AIS Targets from Cuxhaven Right: Screenshot of AIS Targets from LABSKAUS infrastructure in the German Bight with Open CPN and Open Nautical Charts (23.02.2016, 10:45)

The main objective of the Reference Waterway is to have a completely covered area. This area is monitored and the communication technology allows data exchange with surveillance technology for data gathering. The implementation is standardized by using the so called Navibox.

Navibox

The Navibox is a compact sensor data hub which provides navigational data on board as well as data for maritime surveillance systems. The box provides LAN, WLAN and Broadband WAN communication facilities. The minimum setup consists of Radar, Automatic

Identification System (AIS) antenna and wind sensor. But all sensors which are sending data with NMEA0183 or NMEA2000 and Ethernet can be attached.
The Radar is a broadband frequency modulated continuous wave radar (FMCW*)*. The broadband radar is safe of use through low transmission power (165mW, X-Band) as used by Poland River information service [24]. The Radar Tracking Software from Cambridge Pixels identifies radar tracks and processes video. The AIS receiver receives all AIS Messages from AIS Transceiver equipped systems in a 35-100 km radius dependent on Antenna height. The AIS messages include static, dynamic and journey vessel information. A Winds sensor is able to gather wind speed and angle and is connected to the NMEA2000 bus. An Industrial PC (IPC) takes over the sensor stream management, processing and represents a broker of the information distribution. In Figure 5 the data connections are shown.

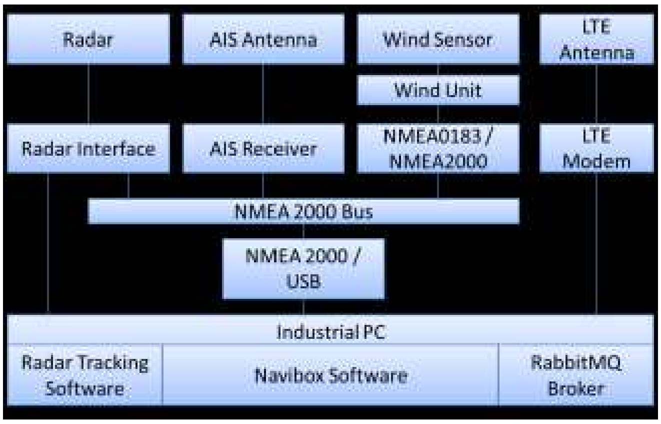

Figure 5. Data connections in the Navibox.

The sensor systems use data stream management after the ideas of the Orocos Toolchain developed by the Orocos Project [23]. This approach from the robotics and automation domain allows the configuration and control over the data streamed from sensor stations. It is enhanced that the control system of the Navibox can be remotely controlled for different scenarios. Commands received from the message passing bus can control the data stream within the Navibox SW and allows changing the semantics, quality and quantity of the sensor data e.g. the wind sensor data will send the actual value only every minute instead of every 100 ms or it will send the average and/or maximum value from a defined period.
If data from a vessel itself is requested the mobile Navibox is our approach. It adds a JRC JRL-21 Differential GPS (DGPS) System that can not only add Position, Course over Ground and Speed over Ground. The DGPS can also add True Heading and Rate of Turn to replace a compass. A chart and multifunctional display allows to over watch sensor data on board. The sensor pole will be attached to a vessel and can now gather sensor data independent from the ship navigation electronics.

Mobile Bridge

For bridge component test (including HMI) LABSKAUS provides a versatile mobile bridge. Three boxes with PCs and two multi-touch displays each can be connected to act as an integrated ship bridge system. It provides a Raytheon Integrated Bridge in its standard configuration (other software is optional) and an open source bridge system. It is linked to eMIR components which provide required navigational data such as compass, GPS, AIS, log, lot, radar, as well as a broad band of communication systems. It can be divided to allow using it in small spaces e.g. on ship. The mobile bridge system allows set up of an experimental bridge on board without interfering with the vessels navigation systems because it is fed by the Navibox or can be used with Haggis as shown in Figure 6: The Mobile Bridge is connected with the HAGGIS [21] Maritime Traffic Simulation (MTS) and a visualization component. The Mobile Bridge can be fed with simulated, then later with real data from the reference waterway and in the last step it can be used on ship with the mobile Navibox for full integrated development. It can enable ship steering also e.g. put the rudder in areas where permissions are given in addition it allows analysing new human-centred designs for information display and controls.

Figure 6. Front: Mobile Bridge Back: visualization of the Maritime Traffic Simulation.

VTS System

An experimental Vessel Traffic Service (VTS) system by Signalis enriches LABSKAUS. It is mobile but usually stationed at the Maritime Research Center in Elsfleth. The VTS system represents the land side of the HMI components. It can be connected to the Reference Waterway as well as to the virtual environment HAGGIS to represent such a system in the testbed. It is used mainly for Human Machine Interface research applications in order to improve the current state-of-the-art designs and new e-Navigation technologies.

5. Interoperability Architecture of eMIR

The testbed interoperability architecture is depicted in Figure 7. Its base concepts are used by LABSKAUS as one physical testbed of eMIR [25]. It is centred on sensor and communication infrastructure with human-machine interaction (HMI) components.

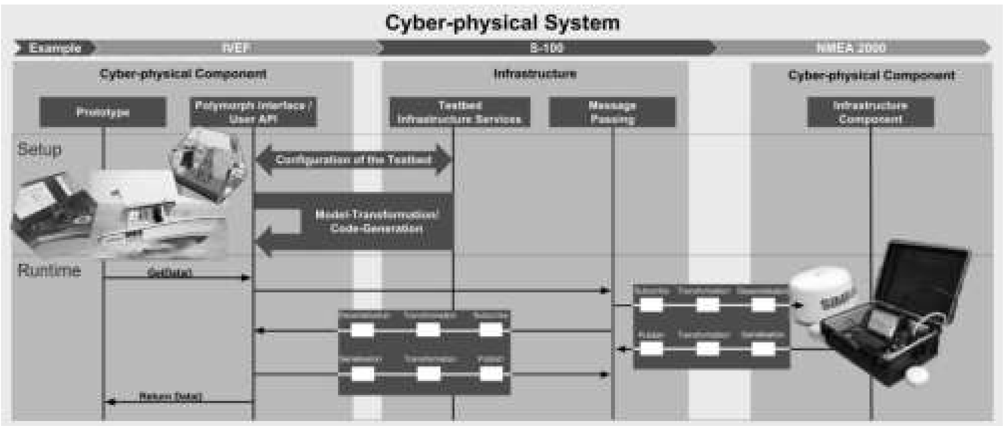

Figure 7. Testbed Architecture of eMIR.

A realisation of this testbed architecture enables the integration of prototypes for present and future maritime cyber-physical systems (CPS) based on various regulations, processes and technical specifications. In terms of openness and compatibility of the testbed, the concept for a polymorphic interface is presented.

The **polymorphic interface** is the entry point for prototypes to be verified and validated. For the physical testbed various interfaces are offered to the prototypes that are going to be integrated. For stakeholder which are interested in the V+V of their prototypes, no modification or integration development is required. The requirement for an interface that adapts to external systems resulted in the concept of the polymorphic interface. For example, an e-Navigation scenario setup based on the overarching e-Navigation architecture developed by the IMO could be set up. The links between the ship-side and shore-side, proposed by the e-navigation architecture, could be realised in an easy way by using the entry point of the polymorphic interface and infrastructure of the physical testbed. The physical links, functional links and operational services as well as the human machine interfaces as established in the e-navigation architecture could be easily integrated into the physical testbed [10].

This approach of a testbed for maritime cyber-physical systems supports model driven system engineering. The safety analysis and simulation-based V+V have proven itself in the system development of maritime components and is therefore pursued within the scope of this work [1]. The presented approach fits the needs of V+V of maritime safety systems in a cyber-physical system context driven by processes and regulations. The testbed architecture enables the testing of models (model in the loop), implementation (software in the loop) and physical prototypes (physics in the loop).

eMIR provides data exchange using S-100 over the message passing bus [9] implemented in internet technology. It is designed under the paradigm of loose coupling and uses a multi-broker communication network which communicates through lanes and knots. It is realised through the open source message broker software RabbitMQ [22]. This system allows controlling the data flow between the components.

The ability to adapt various domain standards should ease the integration of other components. For this, the integration of different systems and their processes are based on modules which perform the data processing (so called data handler). These modules use a data stream management system that processes data streams with the help of defined operators. These operators are represented in the architecture as the small white boxes in the runtime state. For example, sensor data of AIS or radar will be deserialised, transformed from NMEA to S-100 (or other) and transmitted by the message passing bus. Components which need to receive the data are able to subscribe to the message passing bus and receive the data streams. The receiving component can access the message passing bus by a description which is localised in the architecture proposal at the location of the polymorphic interface. By using the polymorphic interface and the scenario configuration, the received data could be transformed from the source format (in LABSKAUS S-100) to the destination format of the prototype, e. g. the inter VTS exchange format (IVEF) for a vessel traffic service (VTS) system) [1].

7. Conclusion and Outlook

In this paper, the status of concepts and implementations of a seamless integrated maritime testbed for the V+V of maritime systems to drive forward the development of autonomous and automated seafaring has been shown. For this, the concepts of MDD development related to the testbed and interoperability concepts to integrate prototypes by a polymorphic interface are presented as well as testbed components of eMIR, such as the data collecting and processing component Navibox, the GNSS related test facilities of the Research Port Rostock or the research boat ZUSE. These testbed components address a wide field of sensor sources, sinks and an infrastructure to build the testbed for V+V. The wide scope of possible tests for e-Navigation technologies in combination with the polymorphic interface offers an open as well as extendable platform for research and industry. eMIR enables various V+V methods to support the development processes and assist these steps with a seamless testbed that reduces the barrier of prototype evaluation and makes the development of an own testbed unnecessarily. In future, the eMIR testbed will be expanded for the development and research of technology for autonomous vessels which seems to be the future of e-Navigation, e. g. USV and ASV. A next step will be to evaluate the flexibility and generality of this approach.

The identification of new scenarios and expansions to enhance the testbed is an ongoing process in research. Furthermore, the maritime testbed will be used to perform metric analyses and modelling based on the results.

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References:

[1] A. Hahn, "Simulation Environment for Risk Assessment of E-Navigation Systems*", ASME 2015 34th International Conference on Ocean, Offshore and Arctic Engineering*, OMAE 2015.

[2] A. Hahn, V. Gollücke, C. Buschmann, S. Schweigert, "Virtual test bed for maritime safety assessment", *16h Marine Engineering Conference*, MTE ISIS 2015.

[3] OS SIS ICD, Issue 1, European GNSS (Galileo) Open Service, Signal in Space Interface Control Document, GSA, European Global Navigation Satellite Systems Agency

[4] Heymann, Frank und Noack, Thoralf und Banyś, Paweł (2013) *Plausibility analysis of navigation related AIS parameter based on time series.* ENC2013, Wien.

[5] Ziebold, Ralf und Dai, Zhen und Lanca, Luis und Noack, Thoralf und Engler, Evelin (3013) *Initial Realization of a Sensor Fusion Based Onboard Maritime Integrated PNT Unit.* TransNav : International Journal on Marine Navigation and Safety of Sea Transportation, Journal Vol.7 (No. 1- March 2013), Seiten 127-134. Faculty of Navigation Gdynia Maritime University. DOI: 10.12716/1001.07.01.17. ISSN 2083-6473

[6] Allianz, "Safety and Shipping 1912-2012: From Titanic to Costa Concordia", http://www.agcs.allianz.com/assets/PDFs/Reports/AGCS_safety_and_shipping_report.pdf, 04.07.2016.

[7] B. Elvesæter, A. Hahn, A.-J. Berre, T. Neple, "Towards an Interoperability Framework for Model-Driven Development of Software Systems", 2005, https://heim.ifi.uio.no/briane/papers/be_interop_esa_2005_paper.pdf, 01.06.02016.

[8] European Commission, "Paris Agreement", http://ec.europa.eu/clima/policies/international/negotiations/paris/index_en.htm, 05.07.2016.

[9] IHO, "S-100 – Universal Hydrographic Data Model.", International Hydrographic Bureau, 2010.

[10] IMO, "Development of an e-Navigation Strategy Implementation Plan," International Maritime Organization, Sub-Committee on safety of navigation, 57, Jun. 2011.

[11] T. Porathe, "ACCSEAS Baseline and Priorities Report," ACCSEAS Project, 2013.

[12] T. Porathe, M. Lützhöft, and G. Praetorius, "Communicating intended routes in ECDIS: Evaluating technological change," *Accid. Anal. Prev.*, vol. 60, pp. 366–370, Nov. 2013.

[13] "An overview of the 'Maritime Cloud' – proposed information exchange infrastructure for e-navigation," DMA, Kopenhagen, SNPWG17-9.3, 2013.

[14] MONA LISA, "Dynamic and Proactive Routes or 'greeen-Routes,'" Sjofartsverket Sweden, Stockholm.

[15] H. Adono, "Smart Ship Application Platform Project (SSAP Project)." [Online]. Available: http://www.mlit.go.jp/common/001039009.pdf. [Accessed: 11-Feb-2015].

[16] G. Mannarini, G. Coppini, P. Oddo, and N. Pinardi, "A Prototype of Ship Routing Decision Support System for an Operational Oceanographic Service," *TransNav Int. J. Mar. Navig. Saf. Sea Transp.*, vol. 7, no. 2, pp. 53–59, 2013.

[17] K. Aichhorn, C. de la Cuesta de Bedoya, P. Berglez, M. Lopez, M. Troger, and A. Kemetinger, "Maritime Volumetric Navigation System," in *Proceedings of the 25th*

International Technical Meeting of The Satellite Division of the Institute of Navigation (ION GNSS 2012), Nashville, Tennessee, 2012.

[18] http://straits-stms.com/Project.html

[19] Dibbern, C., and A. Hahn. "Maritime Traffic Co-Simulation For Analyses of Maritime Systems." In *28th European Conference on Modelling and Simulation ECMS 2014, At Brescia, Italy*, 2014.

[20] Schnieder, Lars und Krenkel, Ralf (2015) *Betreibermodell einer Forschungsinfrastruktur für die Entwicklung intelligenter Mobilitätsdienste im realen Verkehrsumfeld.* In: 16. Symposium Automatisierungssysteme, Assistenzsysteme und eingebettete Systeme für Transportmittel (AAET), 16, Seiten 108-116. 16. Symposium Automatisierungssysteme, Assistenzssysteme und eingebettete Systeme für Transportmittel (AAET), 12.-13. Feb. 2015, Braunschweig. ISBN 978-3-937655-34-5

[21] Schweigert, Sören, Volker Gollücke, Axel Hahn, and André Bolles. "HAGGIS: A Modelling and Simulation Platform for E-Maritime Technology Assessment." In *Proceedings of 2nd International Symposium of Naval Architecture and Maritime*, 733–42. Istanbul, Turkey, 2014. http://www.int-nam.yildiz.edu.tr/2014/cd/1.Proceedings_paperback.pdf.

[22] Rostański, Maciej, Krzysztof Grochla, and Aleksander Seman. "Evaluation of Highly Available and Fault-Tolerant Middleware Clustered Architectures Using RabbitMQ," 879–84, 2014. doi:10.15439/2014F48.

[23] Bruyninckx, H. "Open Robot Control Software: The OROCOS Project," 3:2523–28. IEEE, 2001. doi:10.1109/ROBOT.2001.933002.

[24] Stateczny, Andrzej, and Jacek Lubczonek. "Radar Sensors Implementation in River Information Services in Poland," 1–5. IEEE, 2014. doi:10.1109/IRS.2014.6869248.

[25] Stasch, Arne, Axel Hahn, and André Bolles. "LABSKAUS – A Physical Platform for e–Maritime Technology Assessment." In *Proceedings of 2nd International Symposium of Naval Architecture and Maritime*, 742–52. Istanbul, Turkey, 2014. http://www.int-nam.yildiz.edu.tr/2014/cd/1.Proceedings_paperback.pdf.

[26] Hahn, Axel. "Simulation Environment for Risk Assessment of E-Navigation Systems," V003T02A072. ASME, 2015. doi:10.1115/OMAE2015-41498.

[27] A. Weintrit, "Development of the IMO e-Navigation Concept – Common Maritime Data Structure," in *Modern Transport Telematics*, vol. 239, J. Mikulski, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 151–163.

[28] Damm, W., Boll, S., Fränzle, M., Hein, A., Nicklas, D., Olderog, E. R., ... & Bolles, A. (2015). Interdisciplinary Research Center on Critical Systems Engineering for Socio-Technical Systems-Progress Report.