Global linked simulations - a key to the evaluation of future transport concepts and navigation

R. Grundmann¹ and D. Kang²

¹ Research Associate, Fraunhofer CML, Hamburg, Germany
² Junior Researcher, KRISO, Daejeon, Korea

E-mail: Robert.Grundmann@cml.fraunhofer.de

Abstract. This paper is intended to reflect the achievements of the European Maritime Simulator Network (EMSN Connect) and the Asian Pacific Maritime Simulation Network (APMSN established in 2019), and the achievements of this project, to create a global digital testbed for the entire shipping industry.

1. Introduction

The digitization of transport technologies is developing rapidly. While the focus has so far been primarily on digitized road, rail or in some cases air transport systems, the maritime industry has recently been moving more into focus.

The future design of this digital testbed structure can be used for testing further supporting software and hardware, for evaluating new navigation systems and for large-scale scenarios between (partly) autonomous ships, remotely controlled ships and manned ships, but also for completely different parts of the maritime transport chain.

The European Maritime Simulator Network (EMSN) has set itself the task of increasingly highlighting and exploiting the advantages of collaborative simulation in a digitized world in order to validate exemplary developments of route exchange formats or other services. In addition to testing technological developments, there is a great deal of interest in the ever-growing field of networked simulations in the education and training of seafarers.

Since this network is still relatively young and the possibilities have not yet been extensively researched, some of the currently possible, but also future domains shall be mentioned here, as well as the technical implementation and realization in the different disciplines.

2. History

Till now, Ship Handling Simulator (SHS) experiments have been limited to a small number of simulated vessels in a joint exercise, thus organizational affects or large-scale changes to waterborne processes, procedures and technologies could barely be assessed. According to [1], large-scale virtual test facilities are required to bridge “major gaps with regards to development of safe waterborne connected and automated transport”.

[1]
Such a large-scale virtual test facility exists: The European Maritime Simulator Network (EMSN). Recently, the EMSN has been developed to provide a large-scale test environment for maritime safety. This network evolved from a proof of concept and was operationalized during the EU-funded MONALISA 2.0 and Sea Traffic Management (STM) Validation project and can be regarded today as a baseline technology/testbed for interdisciplinary research in shipping [2].

The EMSN has already been successfully used several times. First, simulations of the current initial situation were carried out, which were then compared with follow-up test runs involving the newly developed STM applications. The exercises were based on navigational demanding traffic situations in the Kattegat between the island of Anholt and the Great Belt Bridge, in the English Channel and various scenarios were also implemented in the Strait of Gibraltar.

Figure 1: Representation of the simulator centers connected and participating in the EMSN Connect 06/2020 [3]

3. What is EMSN Connect?
EMSN Connect is a network of several Ship Handling Simulators (SHS) from different manufacturers, distributed over European locations.
As depicted in [2], the network has a generally applicable network architecture. Starting from the central node, the hub, each center has its own spokes, which in turn send the simulator data to the other centers via the spokes and the hub.

The network sees itself in its basic infrastructure as a platform for the exchange of simulation data and the exchange of voice communication data. These basic services are implemented in IP (sub)networks and enable participants in EMSN Connect to join a networked simulation exercise. The service networks are implemented in the form of Virtual Private Networks (VPN).

The EMSN Connect structure is based on so-called VPN tunnels, which provide secure connections via the Internet. Virtual private networks can be implemented with different topologies. The topology shown for EMSN Connect is a hub-and-spoke topology. It is a variant of so-called site-to-site VPNs that connects multiple sites with intranets to a common virtual private intranet.

The location of the Fraunhofer CML in Hamburg forms the hub for this. All other locations set up VPN tunnels only with the hub in Hamburg. There are no tunnels between the individual spokes.

The entire data is transmitted from a spoke to a hub and from there to all spokes in the network via multicast.

These VPN tunnels are designed with IPSec, data integrity, data confidentiality, authentication of data origin and confidentiality of traffic flow to ensure maximum network security.

To make the simulator data available to different simulators and different simulator manufacturers the DIS standard was used.

"Distributed Interactive Simulation (DIS) is a government and industry initiative to define an infrastructure for linking simulations of various types at multiple locations into realistic, complex, virtual worlds for the simulation of highly interactive activities. In order for DIS to take advantage of currently installed and future simulations developed by different companies, a means had to be found to ensure interoperability between dissimilar simulations" [4].

Since EMSN Connect does not support a common ship model database, an agreement was reached on a number of ship types that are used for visualization throughout the EMSN, i.e. DIS units.

Each simulator manufacturer has its own model database. A distinction is made between so-called OS models (OwnShip) and TG models (TargetShip). A selected list of OS and TS models was assigned a DIS entity number and made uniformly accessible to all participating centers in the DIS application.

The simulator sites which receive the own ship of another simulator in the network map this ship as a foreign ship (TG model). Based on the definitions in the DIS applications, the simulator maps these foreign ships from its model database. Due to the different simulator manufacturers in the network, there may be slight deviations in shape, color and size. However, this can be neglected if the DIS applications in the network are considered in a uniform way, since similar dimensions of the ships in the network were defined for the respective DIS numbers.

To exchange simulation data between the ship simulators, e.g. ship position and motion parameters and AIS messages, the DIS protocol [4] is used. Each ship is identified by a unique entity ID to ensure that own and target ships are correctly connected. In addition, according to DIS, each Entity ID is assigned a DIS entity number indicating the entity type (e.g. ship type and size). The DIS standard offers many advantages, there is an international standard protocol for simulation networks (IEEE 1278), this standard is open and there are no license costs, the infrastructure requirements are easy to implement and simple to handle.

4. Data evaluation and storage

The consideration of the simulations and the implementation of a functioning infrastructure are realized. For the meaningful use of the network in the context of research and development projects, it must now be possible to record the data. Simulation and voice communication data are exchanged within the VPN. Each simulation centre is connected to the Internet via a VPN router, which creates the virtual EMSN subnets between hubs and spokes.
Voice over IP (VoIP) tools are used to establish the radiotelephony connection in the simulator, which is an important part of the training of future navigators.

A specially developed software, the EMSN Data Tracker, is used to map the entire situation of the network and the centres and ships in the exercise based on the DIS Data PDU [5]. In addition to the detailed presentation of the respective status of each centre in the exercise, this also serves to record the data.

Once the data tracker receives the encrypted PDU packets, it first decrypts them and then decrypts the PDU packet based on the different PDU types. After decoding each PDU packet, data trackers visualize detailed information on the data tracker. This way the information is also stored in the database. The database is stored locally on the computer and is available for further analysis after the recording is finished. The movement data of each ship that participated in the exercise can be evaluated in detail. Thus, navigator’s behavior can be more objectively analyses in contrast to pure expert opinion interviews [6].

5. APMSN

The EMSN Connect network has been strengthened during 2019 by the Asian Pacific Maritime Simulator Network (APMSN).

By creating a counterpart of the European network EMSN Connect it was possible to connect two separately working networks in a joint exercise in February 2020. The two networks offer the possibility to hold exercises only in the respective network, but can also be easily interconnected for exercises between APMSN and EMSN Connect.

Due to the same structural setup as EMSN Connect with its own hub, it can operate separately from EMSN Connect. This means that the APMSN has a similar architecture to the EMSN Network and can operate as a stand-alone network. The two independent networks are then connected via different VPN tunnels with different IP security features. To send information between the two independent networks, we use the static protocols EIGRP and NHRP so that the individual networks are stable and secure according to the network guidelines and the encapsulation is done according to the OSI model.

Figure 2: simplified presentation of the infrastructure between EMSN Connect and APMSN
6. Joint Exercise

The presentation of scenarios in simulation networks is not fundamentally different from the runs in a local centre.

On the one hand, the respective objectives of the scenario have to be evaluated, on the other hand the preferred personnel, sailing area and the possible ship types. Once the scenario description has been created, these are implemented in the various simulation locations. This includes standardized local tests as well as short technical test setups which can also be carried out before the simulation itself.

During the run the interactions of the ships can be recorded in the EMSN Data Tracker. These recordings can be enhanced with VoIP recordings to get a complete impression of the run.

An example is a run in the combined network EMSN Connect and APMSN, which reflects a port arrival and berthing scenario in the port of Busan with a container ship planned by KRISO (Korea Research Institute Ships & Ocean Engineering) and instructed by a pilot at KRISO, and two tugs controlled by Chalmers University of Technology / Department of Mechanics and Maritime Sciences (Chalmers M2).

The University of Chalmers used Transas simulators and KRISO used STR simulators respectively. This was the first time a globally networked simulation was run. Further innovations included a port arrival and berthing scenario in the port of Busan using a Chalmers ship planned by KRISO and instructed by a pilot at KRISO, as well as two Chalmers tugs. The pilot's instructions were passed on via the chain of command with repetition and confirmation of the manoeuvres, similar to the real port entrance. However, the manoeuvres were carried out by the experienced crew in Sweden. Particularly noteworthy here is the use of the tugs during the traversing of the ship to the pier.

The objective was to test the implementation of new software and hardware to support pilots in addition to the successful berthing of vessels.

Further implementations of new software are planned for future runs in 2020. Among other things, the ship data provided by the Data Tracker Software will be collected and made available to the pilot for better coordination of the vehicles in the area and timely assessment of potential hazards.

7. A glimpse into the future

The possibilities presented here are only the beginning of the development of a globally operating maritime simulation network. Certainly, with the advancement of automation and autonomination of maritime transport participants in the maritime transport chain, the network will be faced with completely new and diverse tasks in the future. The simulator network can be used in many different ways. The possibilities to take the education and training of seafarers to a new level are as much a topic as the development and testing of new equipment and generally new concepts in maritime transport.

One of the futures and most desirable integrations or innovations in the network may be the integration of (partially) autonomous, autonomous and remote-controlled units [5]. Integrating and evaluating these systems in a networked simulation could be considered within the framework of the two simulation networks. Through the direct connection to traffic control centres and the combination with human simulation participants, possible complex real-world scenarios could be mapped and examined in the networks.

The further development of navigation systems and the integration of these into the bridge is increasingly considered in terms of user interface and user experience factors. The integration of such systems into ship operation requires fundamental tests under as real conditions as possible. Even completely new systems, which are currently used only marginally or not at all on ships, should facilitate the work of navigators in the coming years. To provide important data for the refinement and optimization of such systems, a broadly-based simulator network is suitable.

In a further step, Korea plans to implement a system that will allow simulators to implement the same information available to ports by linking Korean e-navigation services with APMSN technology.
If this is implemented, it is expected that the simulator experiments can also be performed in the real port traffic environment.

In addition to the above-mentioned goals and possible fields of activity of the network, the maritime simulation network is a digital testbed which is prepared for the tasks to come. Beyond the digital infrastructure the network has a large number of maritime experts who are naturally interested in discussing current problems and open questions of the maritime industry and maritime traffic.

In June 2020, the partners of the simulation network were able to show their work to the public in a webinar and let them participate interactively in a run. This first-time public relations effort is to be repeated continuously for different runs.

The goals of this project go beyond a simple online presence. In the future, the society's attention will be focused on ships with different degrees of autonomous systems and their interaction with their human counterparts on other simulator bridges and in the shore stations.

Certainly, this will contribute to an increased public awareness and possibly to a higher acceptance of such systems in society.

The possibilities associated with networked simulations are certainly still in their infancy at the moment, but in view of the current difficult situation with regard to COVID 19, the need for such contactless tests is evident. By building up the network, research and testing can continue on a larger scale, even in times of contact ban.

Acknowledgments
This work received funding from the European MONALISA 2.0 and the STM Validation project as well as from Korean Implementation of Core Technology for Korean e-Navigation Services project. Further, the author would like to thank all participating institutions of the EMSN-Connect initiative named under https://emsn.connect.fraunhofer.de/ for their trust and contribution to this network.

References
[1] European Commission 2017 Connected and Automated Transport - Studies and Reports Available at: http://ec.europa.eu/newsroom/horizon2020/document.cfm?doc_id=46276 [Accessed 10 04 2019].

[2] Rizvanolli A, Burmeister H-C and John O 2015 The Role of the European Maritime Simulator Network in Assessing Dynamic Sea Traffic Management Principles TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation 9, 559-564

[3] https://emsn.connect.fraunhofer.de/

[4] IEEE Std 1278.1-1995 1995 IEEE Standard for Distributed Interactive Simulation Application Protocols

[5] Burmeister H-C, Scheidweiler T, Reimann M and Jahn C 2020 Assessing Safety Effects of Digitization with the European Maritime Simulator Network EMSN: The Sea Traffic Management Case TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation 14 91-96

Olindersson F, Bruhn W, Scheidweiler T, Andersson A 2017 Developing a Maritime Safety Index using Fuzzy Logics TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation 11 469-475