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ISTLAB – New Way of Utilizing a Simulator System in Testing & Demonstration of Intelligent Shipping Technology and Training of Future Maritime Professionals

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ABSTRACT: Exploitation of new technology has a strong impact on the role of the human maritime professional. New knowledge and new skills are needed. This is a challenge for institutions responsible for education of the maritime professionals. The education system is challenged by the following facts: Firstly, the typical lifetime of a commercial ship is several times longer than the typical age of a generation of a computer-based system or application. Secondly, the graduating student should possess necessary skills and knowledge to work efficiently and safely on board a 30-year-old ship and a brand-new ship with the latest technology. Thirdly, the STCW convention by IMO must be strictly applied in education of seafarers, which makes it difficult for the education institutions to include necessary contents on the latest technology in the curriculum.
In this paper, the challenge of education of maritime professionals is discussed and the possibilities of modern simulator technology in testing and demonstration of intelligent shipping solutions and in training of seafarers are presented. Satakunta University of Applied Sciences has established a simulator-based environment, called Intelligent Shipping Technology Test Laboratory (ISTLAB), for development of new applications and for training of maritime professionals to cope with emerging intelligent shipping solutions such as remote monitoring and control of ships and remote pilotage. The structure and functions of the ISTLAB system, remote pilotage as its primary use case, and possible ways of using it in research and education are presented. International co-operation in research of remote pilotage is discussed in the end of the paper.

1 INTRODUCTION

Digital automation and computers have been utilized in maritime transportation systems for more than fifty years. A closer look at the technical development of marine transportation reveals that the pace of the development is not constant. There are calm periods and times of quicker development due to key innovations and breakthrough technologies. Introduction of new technologies has an impact on processes, operational procedures and the requirement of skills and knowledge of the users and other people involved. Creation of the necessary knowledge, new procedures and sometimes even a new culture is an important but also a difficult part of a technical transition. New technology combined with poor knowledge and old-fashioned operational culture is a safety risk.

Early examples of electrotechnical innovations with an impact on operation of ships are the gyro compass and the autopilot, which were developed already a hundred years ago. Another example is the marine radar, which was introduced eighty years ago. Interestingly, although seafaring is often said to be very conservative, it was among the first branches of industry to utilize satellite technology. Transit satellite navigation system was in use already in 1964, seven years after the launch of the world's first satellite. Computer-based digital automation in machinery automation of ships was developed in the late 1970's. This led to the introduction of unmanned machinery spaces [4]. The Dynamic Positioning (DP) system was a revolutionary technology for offshore ships and special purpose vessels. DP systems were introduced in the 1960's [3]. Introduction of digital radar maps combined with advanced digital autopilot and speed pilot functions together with differential GPS positioning enabled navigation of a vessel from port to port virtually fully automatic, yet not unmanned, even in the most demanding archipelago areas. This technology was utilized on board commercial passenger ships in early 1990's [1]. An example of a major technical breakthrough in the 2000's is the Electronic Chart Display and Information System (ECDIS).

Today remote monitoring and remote control of ships, intelligent fairways, intelligent ports, remote pilotage and even autonomy are gaining a lot interest among developers of shipping technology. The shipping industry seems to be in a phase of another technical transition, after some relatively calm years. However, technical transitions and cultural changes within shipping industry will not happen over one night. There is a lot of conservatism in maritime transportation due to the massive investments to existing technology, long lifetime of ships, and to some extent also due to the slowly developing international regulation.

A necessary condition for the acceptance of new technology is that it will bring economic profit for those who are investing in it. If this condition is not fulfilled i.e., as long as there are not enough good business cases supporting the new technology, it will not get confidence among investors on the market. Of course, there are also needs for improvement of safety and environment friendliness of marine transportation. But even these needs must be translated into economic incentives, by means of legislation and international regulation, for instance by the International Maritime Organization (IMO).

2 NEW TECHNOLOGY IS A CHALLENGE FOR TRAINING

Any major technological transition creates a need for updating the skills and the knowledge of those involved with the new processes and new ways of operation. This is a challenge to the education system. The lifetime of cargo ships is typically 25 to 30 years. Compared to this, the lifetime of information technology applications and computer-based systems is short, sometimes only a few years. For this reason, the variety of technologies on board ships is huge. Many cargo ships still in operation represent the technology from thirty or forty years ago, while new ships are based on the latest technology. There can be more than ten processor generations between the 30-years old ship and the newbuilding, just launched from the shipyard. From the education providers' point of view, it is a true challenge to provide the graduating students with necessary skills for safe operation on board a ship of any age between 30 and 0 years!

During times of rapid technical development, another challenge for education providers is the slowly updating standard for training of seafarers. The training standard, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) by IMO [7], must be strictly followed by all accredited training and education providers world-wide. This gives very little room for quick updates of the training of maritime professionals.

Education could benefit from participation in development of new technology - and vice versa. Practical collaboration between a maritime university and a developer of new shipping technology is a win-win situation. The technology company can benefit from the capabilities of the university in doing theoretical and applied research. On the other hand, the maritime university benefits from participating the development process and from being informed about the latest technological innovations, trends, and visions. That information is valuable for keeping the contents of the education up to date.

3 THE POTENTIAL OF SIMULATORS IN TRAINING AND RESEARCH

Simulators have been successfully utilized in training of seafarers already for decades. The pedagogical and economic benefits of using simulators in training of seafarers are evident. Operating costs of a simulator are smaller than the costs of using a full-sized training vessel. Modern navigation and engine-room simulators are highly realistic. Even onboard practice can be partly replaced by simulator training. A good training simulator offers the students a possibility to get hands-on experience of navigation of different ship types, in different routes and ports, under different weather conditions and traffic scenarios. Management of abnormal situations, equipment failures and faults can be trained efficiently and safely in a simulator, as well.

Simulation is also a powerful method in research and development of new solutions. It is a fast, versatile, safe, and cost-effective method for early-stage testing of products and process ideas, before building first prototypes and running full-scale tests in the real environment. The quality of mathematical modelling of the systems and processes is crucial. If the models, algorithms, and the user interfaces are not realistic, the reliability of the simulation results degrade. Today, the realism offered by the leading navigation simulator brands is excellent. In Figure 1, there is a view from the bridge of a modern full-mission navigation simulator (Wärtsilä/Transas NTPRO 5000) equipped with 360 degrees visual system, the navigation simulator of Satakunta University of Applied Sciences, located at the Faculty of Logistics and Maritime Management in Rauma, Finland.

Simulator tests can be used to complement and, in some cases, even replace full-scale tests in the real environment. Compared to full-scale tests, following advantages of simulator tests can be identified:

1. Versatility: it is possible to vary all test parameters within a large parameter space, parameters can be varied independently, it is possible to study rare parameter combinations
2. Adequacy: while it is possible to define all test parameters, irrelevant or less interesting test runs can be avoided, and resources be allocated to essential test scenarios
3. Time-efficiency: setting up test arrangements and changing from one test scenario to another is quick, no extra time is consumed in transportation or in waiting for proper test conditions etc.
4. Labor-cost savings: no need for extra personnel e.g., crew of test vessels
5. Safety: there is no danger for humans, property, or environment; all accidents will be simulated as well
6. Environment-friendliness: no harmful emissions are caused; energy consumption is low compared to full-scale tests
7. Cheap and quick to identify failures: design flaws and other mistakes can be identified early, costs of correcting a failure are lower than in a later phase of the development process
8. Cheap to make modifications: alternative solutions can be tested without the need to build new prototypes or to set up new test installations

Figure 1. The main bridge of the navigation simulator at SAMK, Rauma

Anyhow, simulator testing has obvious limitations. Simulation is always an approximation of the phenomena of the real world. Simulation can never be better than the undelaying models it is based on. The accuracy and realism of modelling the actual systems and processes is crucial. Another major difference between simulation and a full-scale test in real environment is psychological of its nature. The experienced risk of using the simulator versus using the real equipment has an impact on the human behavior, i.e., the risks of harmful consequences of wrong decisions or actions of the human operator. It is mentally more stressful in demanding conditions to navigate a real ship than to navigate a simulated ship! Full-scale tests can also reveal unpredicted features, design flaws and malfunctions of the real equipment that were not known and hence not included in the "ideal" models of the simulated equipment. Also, some other factors, such as trainer–trainee interaction, may influence perceived level of the fidelity of the simulation, as addressed by Wahl [11].

One could ask whether simulation can reveal new information about the simulated system, when operation of the simulator is solely based on algorithms, defined in advance by the designers of the simulator! This question is relevant when the simulator is based on deterministic algorithms. However, simulation-based research makes sense when the studied system is complex, including a lot of interaction between subsystems and virtually infinite number of possible input parameter combinations. In such case, simulation can provide new information about interactions and interdependencies between the subsystems of the simulated entity, under a large variety of input parameter combinations. Moreover, when human action is included, simulation becomes non-deterministic.

A navigation simulator is a complicated set of subsystems, which represent processes of the ship and the real world around it. Each of these processes is modelled as accurately as practically possible. The processes are interacting with each other in the form of information and energy exchange. Modeling of these interactions is a vital part of the simulation. The interface between the technical system and the human operator is essential in simulation of socio-technical systems. In navigation simulators, the bridge equipment and the visual system describing the surroundings of the ship are essential parts of the human-machine interface. In advanced flight simulators, realism is enhanced by simulating the accelerations of the plane by moving the cockpit by means of a hydraulic system. In most maritime simulators wave-induced movements of the ship are simulated by means of the visual system only, i.e., not by moving the bridge.

An important topic for research on socio-technical systems is the interaction between the human operator and the technical system. Interesting questions for research are:

– Is the information provided by the system sufficient for safe operation?
– Does presentation of the information support safe operation?
– Is the operator able to maintain proper situation awareness in all situations?
– Is there a risk for information overflow, i.e., does the system overload the operator with non-essential information and by doing it, block reception of critical information?
– Where are the biggest risks for human error and how these risks could be minimized?
– Is the ergonomics of the human-machine interface properly considered?

It can be concluded that simulation, when its limitations are appropriately considered, is a cost-effective, safe, and fast method to speed-up development of new technologies. It must be also noted that all exceptional conditions and rare phenomena cannot be covered by full-scale tests in real environment, either because of the rarity of the phenomena or unacceptable risks associated with tests.

4 ISTLAB – THE INTELLIGENT SHIPPING TECHNOLOGY TEST LABORATORY

A platform for development of new solutions of intelligent shipping has been built at the faculty of Logistics and Maritime Technology of Satakunta University of Applied Sciences in Rauma. The laboratory, called ISTLAB (Intelligent Shipping Technology Test Laboratory) is an extension of the navigation simulator of SAMK. The laboratory is an outcome of the ISTLAB project, funded by the European Regional Development Fund of EU and it is the first of its kind in the world. The project is carried out in cooperation with the Finnish Geospatial Research Institute and the Finnish Meteorological Institute. The supporting partners are the Finnish Transport and Communications Agency TRAFICOM, the Finnish Transport Infrastructure Agency VÄYLÄ, Finnpilot Pilotage Ltd, Port of Rauma, Wärtsilä Finland Oy, Fintraffic Vessel Traffic Services Ltd and WinNova Länsirannikon Koulutus Ltd [6].

4.1 *General Structure and the Basic Operation Scenarios of ISTLAB*

The purpose of ISTLAB is to serve as a testbed and research platform for new innovations of intelligent shipping technology. ISTLAB consists of a simulator system at the Faculty of Logistics and Maritime Technology of Satakunta University of Applied Sciences (SAMK) and data interfaces to equipment in the main fairway and the port area of the Port of Rauma.

The core of ISTLAB is the full mission navigation simulator of SAMK. ISTLAB is an extension of the navigation simulator and it is designed to cover the following degrees of automation for Maritime Autonomous Surface Ships (MASS) identified by the Marine Safety Committee of IMO [10]:

– Manned ship with automatic functions (Scenario 1)
– Remotely controlled manned ship (Scenario 2)
– Remotely controlled unmanned ship (Scenario 3)

Additionally, the ISTLAB simulator covers the following operational scenarios:

– Remotely monitored manned ship (Scenario 4)
– Remotely piloted manned ship (Scenario 5)

To be able to cover the five Basic Operational Scenarios listed above, the ISTLAB simulator system contains the following elements:

– the manned own ship equipped with local control mode and in a remote-control mode
– the remote Monitoring & Control Unit (MCU)
– the Remote Pilotage Unit (RPU)
– the sensor equipment in the port area (i.e., cameras, radars etc.)
– the VTS station

The general structure of the ISTLAB simulator system is shown in Figure 2.

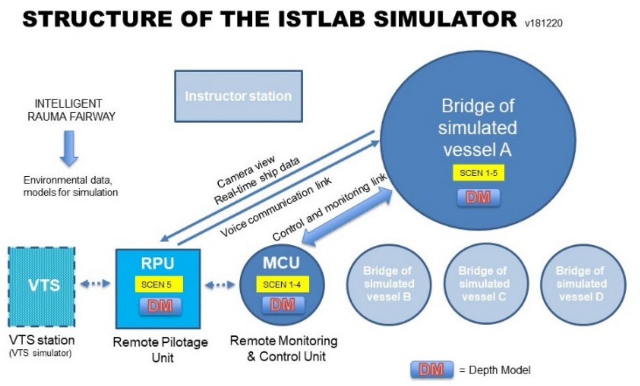

Figure 2. General structure of the ISTLAB simulator system

The five circles on the right side of Figure 2 together with the instructor station on the top represent the existing navigation simulator system of SAMK. One of the existing bridges is converted to MCU when scenarios 1 to 4 are being used. RPU for scenario 5 is placed in a separate room. Optional VTS station has not been implemented yet. It can be combined with the existing instructor station or placed in a separate room. There is also a possibility to utilize a remote VTS simulator for implementation of the VTS station.

5 USE CASE: REMOTE PILOTAGE

A concrete use case was chosen as a reference for testing and verification of the design and operation of the ISTLAB simulator. Remote pilotage was selected to be the use case. Remote pilotage is defined at the International Standard for maritime Pilot Organizations as “an act of pilotage carried out in a designated area by a pilot licensed for that area from a position other than on board the vessel concerned to conduct the safe navigation of that vessel” [8]. In other words, during remote pilotage, the pilot is not physically present on the bridge of the vessel but communicates with the ship’s deck personnel from a remote pilotage station using a VHF radio or corresponding equipment.

Remote pilotage is a commercially potential application of the intelligent shipping technologies. There is a natural demand and need for the technology on the market. It is proposed that remote pilotage can significantly reduce the costs of pilotage, without increasing safety risks. The technology is interesting from all stakeholders’ point of view, i.e., the port, the pilotage service provider, and the shipping company. It was estimated, based on a case-study in Australia, that the remote pilotage technology would pay back the investment in five years if the amount and type of the vessel traffic of the port in concern are suitable for the technology [2].

However, before remote pilotage can be taken into wider use, there are several items to be studied and many questions to be answered. Topics for further research and testing are, for instance, technical requirements of the vessel to be piloted, technical requirements for the port and the fairway, the skill requirements for the deck officers of the piloted vessel and the pilot, responsibilities and duties of the parties involved, legal aspects, safe practices, standards, and cyber security issues.

The main components of the ISTLAB simulator setup for remote pilotage are the bridge of the vessel to be piloted and the control room for the remote pilot. In Figure 2, the bridge of the piloted ship is described by the big circle (Ship A), and the remote pilot unit is marked with the abbreviation RPU. The bridge of Ship A has a 360 degrees visual system. Data from Ship A is transmitted to RPU utilizing the internal data network of the Wärtsilä simulator system. A sample configuration of the displays at RPU is shown in Figure 3.

Figure 3. Displays of the Remote Pilotage Unit

The basic navigation information, i.e., the real-time position, speed, and heading on the electronic chart display as well as the essential information about the operation of the propulsion and the rudders of the ship are shown on the monitors of RPU. In addition, a large selection of optional real-time data is available at RPU, describing the status of the technical systems of the ship. Virtually any information about the simulated vessel could be displayed at RPU. This excellent versatility enables testing of any combination of information sent from the piloted ship. It is an important topic for research to define the minimum amount and type of information that the pilot at RPU must be provided to maintain proper situation awareness and the ability to carry out remote piloting safely. It is also possible to analyse the effects of transmission delays, disturbances, and errors to the accuracy and safety of the pilotage.

Optionally, a camera view through the windows of the bridge, or a view from a fairway camera can be displayed at RPU, as shown in Figure 3.

The system enables studying and training of remote pilotage in varying weather conditions. As part of the ISTLAB project, The Finnish Meteorological Institute installed wave, current and wind sensors to the main fairway of the Port of Rauma to collect information about the real weather conditions in the area. This information has been utilized to model the weather conditions as realistically as possible. Accurate depth measurements of the main fairway of the Port of Rauma are also utilized to create a 3-D depth model of the fairway. This model has been added to the simulator to maximise the realism of the simulation of the behaviour of the ship in the fairway area. The depth model makes it also possible to test the Bathymetric Surface Product Specification S 102 by International Hydrographic Organization (IHO) for displaying the depth information on ECDIS [5]. All tests can be conducted using many different ship types.

The human element, i.e., behaviour of the pilot and the officers on the deck of the piloted ship can be analysed in several ways. It is possible to record all control actions and the voice communication, and the whole exercise analysed afterwards. The operation of the pilot or the officer of the watch of the ship can be analysed also using eye movement tracking. Eye movement tracking reveals the importance and the usage of different items shown on the displays of the user interface of RPU and the ship's bridge. According the first tests in ISTLAB the usage of available information varies significantly during the pilotage process [9]. The eye movement tracking glasses if ISTLAB are shown in Figure 4.

Figure 4. The eye movement tracking glasses of ISTLAB [9]

The Covid-19 pandemic caused a delay for commissioning of the ISTLAB platform. However, ISTLAB has been used in a preliminary study of remote pilotage. Test arrangements and results of the tests are described by Lahtinen et al. [9].

ISTLAB has already turned out to be a useful and versatile environment for research. Remote pilotage will be one of the research areas in the future. Satakunta University of Applied Sciences is presently looking for international partners for the new ISTLABnet project initiative. The objective is to establish an international network of testing and development facilities for remote pilotage and to continue research on the following areas: Risk management of novel navigation services, connectivity and information exchange, emerging new roles and responsibilities, standardization of procedures, training and knowledge base requirements, and cybersecurity challenges. Combination of simulators into one network over the internet will open possibilities for testing of the technology in truly international environment, in a setup of a remote pilotage unit located in one country and the ship to be piloted located in another country, manned with individuals with different native languages and having different cultural backgrounds. This will be an interesting setup, since seamless and error-free communication between the ship and the remote pilot is crucial for the safety of the operation, as well as the sensor information transfer and maintenance of situation awareness in both sites.

6 SUMMARY

Rapid development of shipping technology is a challenge for the maritime education providers. New competence requirements for maritime professionals are set by the developing technology, while the traditional seamanship remains still relevant and necessary. Combining education with research of the new technology can help maritime universities to cope with the challenge. Satakunta University of Applied Sciences (SAMK) has established a simulator-based laboratory called ISTLAB, for research, testing and demonstration of intelligent shipping technology. ISTLAB is an extension to the navigation simulator of SAMK. Remote pilotage was chosen as the first use case for ISTLAB. In addition, the simulator is designed to cover different levels of autonomy, i.e., remote monitoring of a manned ship, remote control of a manned ship, remote monitoring of an unmanned ship, and remote control of an unmanned ship. These technologies require plenty of development work – not only on the technical aspects, but also within legislative matters, share of rights and responsibilities, standardization, and risk management, to name some. Close collaboration with the forerunners of shipping technology helps the university to anticipate new skill requirements of seafaring professionals and to modify the education programs accordingly. It is important that new generations of seafarers have a good understanding of the principles of emerging technologies.

Development towards higher levels of autonomy in sea transportation will be defined by commercial aspects. A sound business case is a necessity for the development. The breakthrough of autonomy in sea transportation has not yet taken place. For this reason, remote pilotage was chosen as the primary use case for ISTLAB. However, ISTLAB can be used for research and demonstration of other applications of intelligent shipping technology as well. The research on remote pilotage will extend into collaboration with international partners in the future.

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