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# Designing of human activity at sea in the navigational simulators environment

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**Abstract**
From time immemorial, the main type of human activity at sea was transport of goods, then fishery, exploration of overseas territories, combating enemy's vessels etc. The twentieth century visualized clearly also a military activity, whereas the latter part of the century also an industrial one on the continental shelves. Progress in these fields was the leading motive power considerably increasing human activity at sea beyond transport. The paper shows results of research work on designing of human activity at sea in the navigational simulators environment. These research works have been conducted in Institute of Navigation and Hydrography Polish Naval Academy.

## Introduction

From time immemorial, the main type of human activity at sea was transport of goods, then fishery, exploration of overseas territories, combating enemy's vessels etc. The twentieth century visualized clearly also a military activity, whereas the latter part of the century also an industrial one on the continental shelves.

The methods of facing the above challenges, sometimes very sophisticated, required much more information about their legal and operational environment (traffic of vessels, undertaking the decisions concerning the tasks at on-shore centers etc.), whereat the necessary information had to be of higher accuracy and reliability. Progress in these fields was the leading motive power considerably increasing human activity at sea beyond transport. The problems of accessibility, credibility and reliability were described in details in [1]

Wherever the transport tasks are considered, it is necessary to focus on safe navigation of a ship, limited to its hull and the hull's inside, in relation to any navigational obstacles, also to hydrological and meteorological phenomena.

In case of other than transport tasks, one should be concentrated on safety of vehicles on crossing the sea, the same as it is for ships involved in transport only, whereas on waterways where other tasks are performed, also on technologies of performing the works carried out thereon.

## Production of navigational and hydrographic information

Navigational and hydrographic information required for performance of the assignments has to be produced and delivered to ship crews. The information is produced by navigational and hydrographic maritime services, while for using thereof in optimal way there are appointed crews of ships, appointed to perform their tasks at sea. The safety tasks, necessary for navigational process in transport, are carried out by the Maritime Administration, which performs standards of IMO and IALA, taking into account also the navigational and hydrographic characteristics of specific water area, subject to its supervision. To meet any needs of technologies applied to perform the tasks other than transport, there are worked out standards assigned

by institutions which carry out the jobs – usually these institutions are responsible for production of information required in the process in progress.

Such a division results from many criteria; for transport by sea the most often there are mentioned "assurance of safety at sea and anti-terrorism protection of ships, protection of environment against pollutions from ships and effective navigation of ships at sea in respect of economy and operating". In case of realization of tasks other than transport and recreation, apart from assurance of safety at sea, the aim is to simplify or to enable this realization of tasks. The problems of safety at sea and anti-terrorism protection of ships were described by the Authors in the work [2].

To reach the goal in transport by sea and other tasks carried out at sea it is necessary to generate a considerable quantum of information concerning navigation and hydrography. The respective information, together with the conditions of tasks performance is produced in the system of navigational and hydrographic protection (NHZ). The NHZ system was defined as a set of undertakings of navigational and hydrographic services, mutually correlated in respect of their goal, place and time, and performed in accordance to a uniform plan and intention, for the benefit, understood as effectiveness of activity at sea.

An objective of the NHZ system is to produce necessary navigational and hydrographic conditions to assure safe sailing, effective tasks performance and marine environment protection against pollutions, generated by human activity at sea. Improvement in ships traffic effectiveness requires a necessity of prompt development of ship navigation system development XXI [3].

Performance of tasks other than transport by sea demands the ship crew's competence in assurance of navigation safety, as well as handing over the navigational and hydrographic information, required for the task performance technologies. However, producing this information is not a skill which has to be possessed by crews of the ships performing navigational process. Therefore, there is a certain scope of works which have to be done to produce the information allowing assurance of safety and effectiveness of navigational process. To satisfy the above needs, the NHZ tasks are realized by the State navigational services, which are responsible for navigational safety by force of law. Apart from the tasks performed aiming at safety of navigation, there is realized and financed by the State as well, production of the navigational information, necessary for the assignments carried out by the Navy, Border Guard and Maritime Administration etc. Using the funds off the budget, the navigational and hydrographic information at sea is produced by institutions which perform those assignments.

In effect of lacking appropriate correlation of the assignments, the information is often doubled by different institutions. Therefrom a necessity of creating a data bases networks appears; it would open a chance to obtain, with unlimited access, any information essential for safety and effectiveness of sailing, however, the information important for technologies of the performed assignments should be spread on a basis of a qualified access. The problems of automation in processing the available navigational information, required to rise the navigation safety level in respect of radar navigation, was described also in the work [4].

## The navigational information acquisition methods

Performing of various tasks induces frequently differentiation of the information acquisition methods. Acquisition of the information using the true models at sea is burdened with really high costs. In such situation certainly the equally efficient but not so expensive methods are either sought or worked out.

At present the digital models are usually applied; they enable to replace inexpensively and easy the research methods used so far. The essential matter is to let the interested parties be aware that the information remains available.

Simulation tools enable to determine more realistic and accurate data for examination and assessment of waterways. Simulation is aimed at identification and reduction of risk in activity of sailors in specific conditions of waterways, channels and port water areas. They comprise the quantity and quality assessment of channels and waterways configuration.

As regards the simulation system the general requirement thereto is a possibility of applying multilevel simulation software, including effective tools for re-positioning and designing safe waterways and port facilities elements.

In the Navigation and Hydrography Institute of the Naval Academy since the eighties of XX century there were realized the navigational and hydrographic projects, referring to protection of human activity at sea. It was feasible owing to a wide set of simulation tools, which can be used for designing the both – waterways systems and navigational facilities. Planning of NHZ in simulators' virtual environment allowed to design the virtual equivalents of real sectors of Polish maritime territory and

to evaluate a quality of the produced elements of NHZ before they were truely constructed at sea water areas.

The selected tools (simulators and laboratories) used for assessment of the existing, newly designed waterways and other navigational water areas, also several results of the carried out research works are presented below.

The most advanced in years research tool, owned by the Naval Academy, is its manoeuvring tank. It is the only research tool covering 62 $m^2$ of area, which was constructed in the latter part of the XX century.

Fig. 1. Manoeuvring pool [http://www.amw.gdynia.pl]

In the time period when simulators based on electronic computer science were unavailable, the pool enabled to carry out the works on structures of hydro-technical elements of sea and inland ports. Thus, it offers a possibility of creating a model of any designed structure, as for example a harbour quay, and next examining behaviour of vessels' models in a function of simulated hydro-meteorological conditions. Due to availability of the advanced navigational manoeuvring simulators, the manoeuvring pool is used to carry out research projects on analysis of vessels behaviour in non-typical navigational conditions. Recently behaviour of two different classes' vessels on their running aground was researched. The investigations included various types of sea bottom and different methods of heaving the vessels.

The first integrated multitask simulator of the navigational bridge was installed in INiHM in the latter part of the XX century (Fig. 4). It was provided with 8 individual research stations (Fig. 5).

In the following years the next simulators were acquired and used both for research works and educational reasons. Three multitask stations with visualization systems were installed (Fig. 6).

Fig. 2. Washing out sea bottom by a rescue ship before re-floating the vessel [archives of Department of Ship's Operation]

Fig. 3. Heaving the vessel with the assistance of a tow boat [archives of Department of Ship's Operation]

Fig. 4. Integrated multitask simulator of the navigational bridge [archives of INiHM]

Fig. 5. Individual laboratory stations with systems of visualization [archives of INiHM]

Fig. 6. Multitask simulation stations with visualization systems [archives of INiHM]

In 2011 the Basic Navigation Laboratory was built (Fig. 7); it was based on 16 individual stations. Each of the stations was equipped with two simulators:

– classical navigation manoeuvring simulator with the visualization channel and ECDIS system, produced by TRANSAS;
– navigational calculations simulator with ECDIS system, produced by C-map Jeppesen Marine.

Thus, one laboratory station is provided with two systems of electronic charts, which at present are equipments of decided majority of contemporary maritime transport means.

Fig. 7. Basic Navigation Laboratory [archives of INiHM]

In last two years the Navigation and Hydrography Institute of the Naval Academy grew rich with the next research laboratory: Integrated Simulator RADAR-ARPA/ECDIS-WECDIS (Fig. 8). The simulator is equipped with 8 specialistic stations with wisualization systems and, as the first simulator in Poland, is fitted with the system of electronic charts with additional military layers (AML).

Fig. 8. Integrated simulator RADAR-ARPA/ECDIS-WECDIS [archives of INiHM]

Conducting research is feasible by means of software, installed at the monitoring and control stations.

Fig. 9. Instructors' stations and servers [archives of INiHM]

## The exemplary research projects referring to NHZ

Such a great research potential enables to carry out any investigations in NHZ subject. Within last twenty years many projects comprising modelling of sea areas and port facilities were performed. Some selected projects realized in various research fields are presented below.

In nineties of the last century there was performed the work allowing to design and to construct the pier in the fishery harbour in Hel locality. The executed calculations correctness analysis was verified basing on tests at the manoeuvring tank. The project was implemented for benefit of the Town of Hel community (Fig. 10).

Fig. 10. The fishery harbour in Hel. The designed fish pier is marked yellow [http://www.maszwolne.pl]

Within the frameworks of the feasibility study referring to the hydro-technical works intended for execution at the area of the Vistula Lagoon, the virtual design of the cross-cut through the Vistula Spit was worked out (Fig. 11).

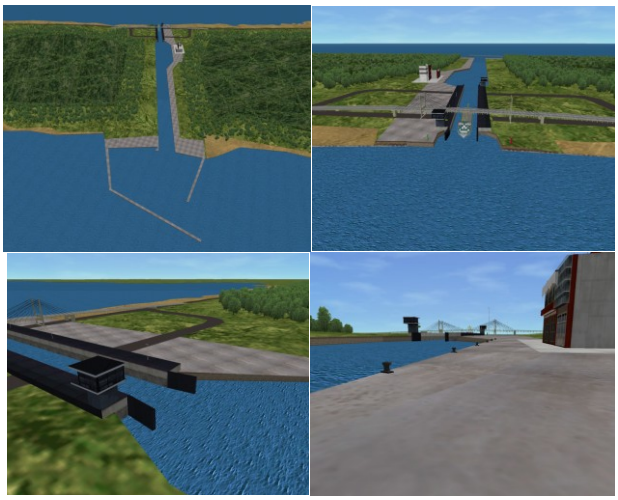

Fig. 11. The virtual model of the Vistula Spit cross-cut [archives of INiHM]

The research projects, apart from their utilitarian objects, are aimed at education as well. Arousing students' interest in scientific investigations and research work provides continuity of the works realization and steady scientific development. Examples of performance of tasks in Navigational and Hydrographic Protection planning presented in student dissertations are two already realized projects. One of them is the virtual model of the Vistula Śmiała river mouth (Fig. 12).

Fig. 12. Virtual model of the Vistula Śmiała river mouth [5]

The next project comprised construction of a model of the marina in Puck (Fig. 13).

Each of the projects performed in the simulator environment reproduces in possibly precise way the hydrological conditions also the port and waterways system facilities. Moreover, also the meteoro

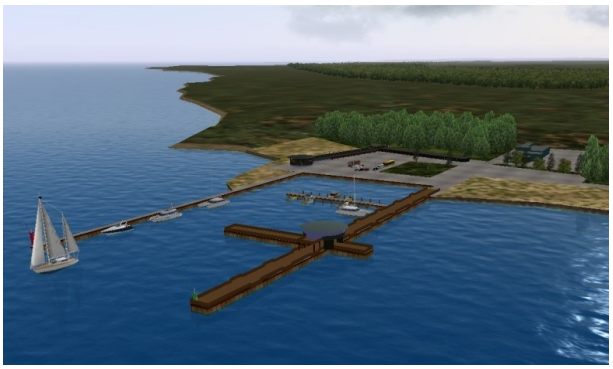

Fig. 13. Virtual model of Puck marina [6]

logical conditions are simulated basing on observations reported in accessible archives. A process of preparing the water area to the research in the navigational simulator's environment is described below.

## Examination of safe ships traffic conditions illustrated with an example of the Motława River traffic

To make easier an access of pedestrians coming from the centre of Gdańsk to Ołowianka Island, it was decided to build a foot-bridge across the Motława. Thus, the work was aimed at determination of conditions and navigation safety on the Motława River after completion of the foot-bridge to the Ołowianka Island. The following assumptions were taken into consideration on preparing the analysis:

1) the movable foot-bridge is to be low, considering the quay level at the settled location point (Fig. 14);
2) the foot-bridge is to be of a vertical drawbridge structure, two-wing or horizontally rotational, with its pylon situated at the Ołowianka Island side and turning direction towards the quay at the sewage pumping station, with a length of the movable span allowing the fairway to be 40 m wide;
3) the drawbridge within the Nowa Wałowa street, of an inside distance of 9 m above the highest water level or a tunnel under the river (according to the local development plan's assumptions);
4) a possibility of towing MS Sołdek to periodical surveys and overhauls reserved;
5) traffic of tourist yachts and motorboats from the designed marinas and the existing one:
   a) the existing one – on the Nowa Motława at Szafarnia street;
   b) the designed:
      – on the Na Stępce Canal with the Kamieniarski drawbridge;

– on the Stara Motława, after reconstruction of the two bridges and converting them to drawbridge structures;
– the new mooring quays – after repair and putting into service according to the designs worked out for the Maritime Office.


Fig. 14. The designed foundation of the foot-bridge and the drawbridge across the Motława River [Earth Google]

For carrying out the detailed navigational analysis in the function of the made assumptions, it was decided to build up from scratch the Motława River water area and the adjacent fragments of Gdańsk in the navigation and manoeuvring simulator's environment. The work was started from preparation of the map base (Fig. 15).

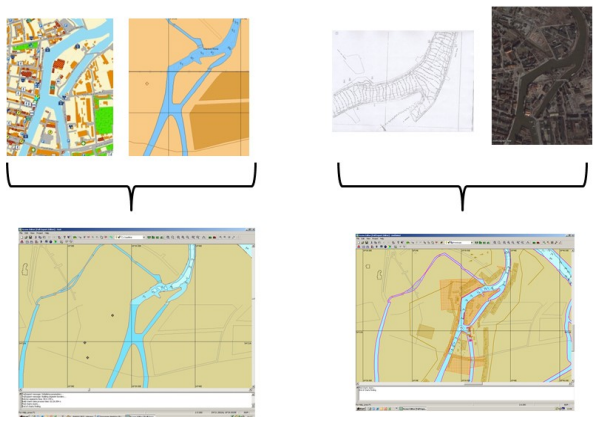

Fig. 15. Construction of the map base presenting the Motława River fragment [7]

For this purpose all the available navigational charts on paper and any others were digitalized; there was also used a cell of the electronic map issued by the Polish Navy Hydrographic Office. This way prepared map base was covered with the up-to-date hydrographic soundings and the available satellite photographs of the water area under discussion (Fig. 16).

In effect of applying the lab software together with the textures library, there was obtained the virtual model of the Motława River sector; its three-dimensional model was corresponding to the

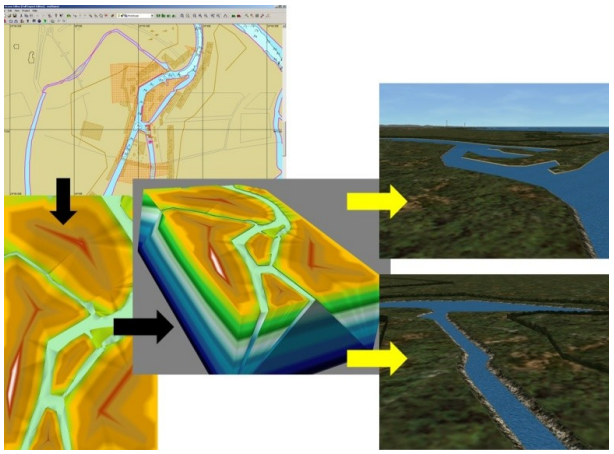

Fig. 16. Construction of the virtual Motława River water reservoir [7]

available satellite photographs and the bathymetric plan of the river. Such an approach to the set out research problem performance enabled the team to create a research model of the water reservoir, reliable and adequate to the real one.

The next phase was creating the town infrastructure and port facilities, situated around the water area under research. It was realized by 4 stages:

– stage 1: collecting data on the objects through taking photos, which in the further part of the project are to be used as textures, which enable realistic projection of the structures in the simulator environment. To reach this goal, over 700 photos of the structures adhering to the sailing area were taken. The essential data was also the information regarding real dimensions of a building and its location;
– stage 2: composition of structural grids of the created objects in 3D modeling environment 3D;

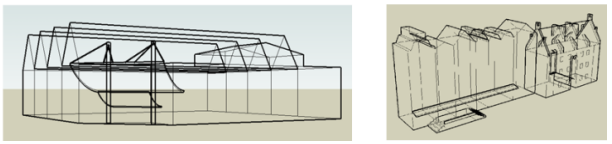

Fig. 17. Exemplary realization of stage 2 [7]

– stage 3: joining (closure) of points and filling the created objects' areas;

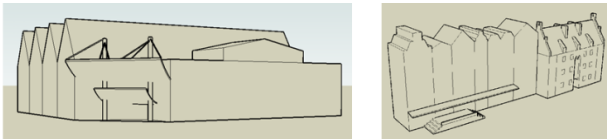

Fig. 18. Exemplary realization of stage 3 [7]

– stage 4: covering the created objects with textures (Fig. 19).

The whole of the created in 3D environment objects, together with movable objects available from the simulator's library were put on top of the

created model of the Motława River water area, to display the virtual picture of the real inland marine water area (Fig. 20).

Fig. 19. Exemplary realization of stage 4 [7]

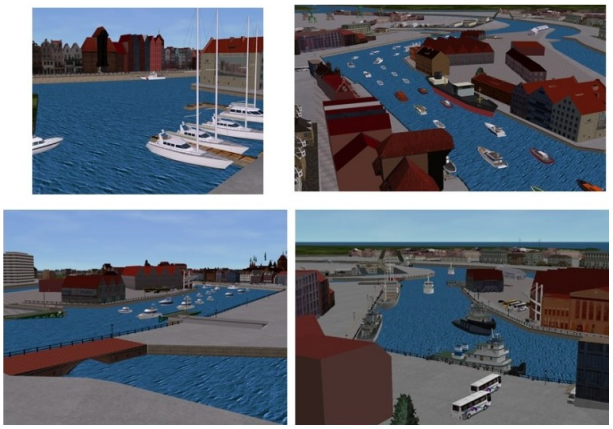

Fig. 20. The virtual sector of the Motława River and the Old Town in Gdańsk [7]

This way prepared water area model was used for the studies on assessment of navigation safety evaluation. The research carried out in the simulator's environment enabled appraisal of vessels' crews behaviour. Whereas the studies realized at the same time using the map base (Fig. 21), allowed to evaluate safety on the whole water area.

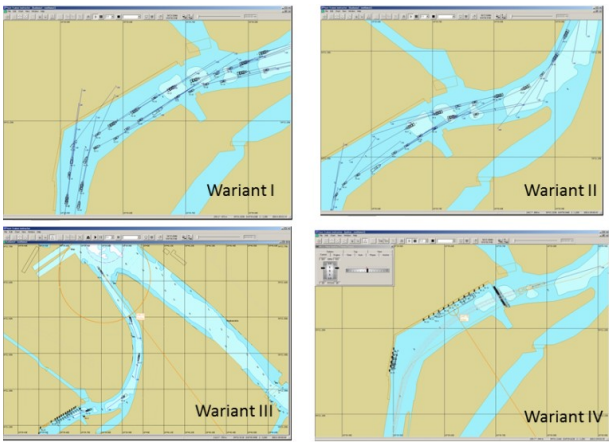


Fig. 21. Two dimensional visualization of simulation tests [7]

In general the conducted research confirmed that the structures intended for construction are not to cause any such substantive threat to safety of navigation at the Motława waterway to withdraw from the decided construction of the crossovers. The proposed reconstruction of two bridges would additionally simplify navigation of recreation ships [7].

## Conclusions

Production of navigational and hydrographic information, required by any type of human activity at sea, is a fundamental element, conditioning maintenance of high navigation level on marine and inland areas.

At the time of the financial world crisis and the society familiar with computer sciences, the navigational manoeuvring simulators appeared to be unquestionable high-efficient and inexpensive tool, to support designing of marine water areas and adjacent facilities.

Realization of research works on planning NHZ in computer environment enable constant interdisciplinary development of technical sciences not only in navigation subject but also in transport, computer sciences and any others, which are necessary in processes conducted in NHZ field.

The navigation safety analysis carried out on the Motława River was a basis for the next actions realized by the City Hall in Gdańsk. The actual status of the investment project is as follows; after reaching the decision in architectonic competition in October 2012, the relevant technical documentation and specifications are under realization.

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