

## Construction and functionality of integrated interactive simulator for inland ship navigation

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### Abstract

The following paper describes construction and functionality of the newly developed shiphandling simulator for the inland navigation (called InSim), that was constructed as a part of research project at Maritime University of Szczecin. Problems of construction process and simulator ergonomics were presented. Fidelity of the simulation with respect to real environment, as well as details of all subsystems were discussed.

### Introduction

The first task in the process of InSim creation was to determine all the desired equipment and its functionality. It was also important to recognize all features of the inland environment, so it could be recreated in the simulation. The analysis of the assumption data was made, simulator blocks were constructed and, where necessary, real devices were installed. All subsystems were verified allowing for identification and correction of errors. The following paper describes key elements of the simulator and all stages of its construction.

### Assumptions for subsystems construction

After detailed phase of planning three subsystems, that are vital for the simulator performance and have to meet project assumptions, were chosen.

#### a) Positioning system

It is based on GPS/DGPS model and takes under consideration:

- Satellites visibility – consistent with the ephemeris data;
- GPS errors – with an option for dynamic change of position accuracy;
- Signal obstruction – accuracy decrease due to obstructions by other objects;
- Differential corrections, including EGNOS system.

To maintain communication compatibility with real devices, used in the simulator, the NMEA 0183 protocol is used. It utilizes so called sentences to transmit data between devices. The sentences consist of ASCII characters. Single sentence can be as long as 82 characters. Every sentence starts with a “\$” sign, next are sentence identifications, data fields separated with comas, “\*” sign, checksum and carriage return and line feed symbols: <CR><LF>.

The following sentences of NMEA 0183 protocol were chosen: GLL, GGA, VTG, RMC, GSA, GSV, ZDA, WPL, RTE, and AAM. These frames transmit the information, generated by the positioning system to other subsystems. Function of the positioning system is expanded by an option to use external \*.dll libraries that can be used e.g. for error generation.

#### b) Automatic steering system

Autopilot was programmed in two different versions: one based on classic PID regulator with adjustable coefficients connected with Rudder, Yaw and Trim settings, and the other one as an adaptive autopilot. Also a smooth time flow controller is provided.

#### c) Automatic Identification System

AIS emulator is able to simulate up to two hundreds objects. Each of the simulated unit should be

autonomous, which means that it is able to load its own route and follow it automatically. It allows to generate AIS messages in AIVDM and BSVDM formats. There is also provided error handling, so the system can detect fault messages and log information about their occurrences.

**Construction and functionality of inland simulator**

General overview of simulator construction is shown on the figure 1.

During construction of the conning panel two different visualizations were created:

- a) For Astraada touch panel;
- b) As a computer virtual panel.

Both visualizations are shown on figures 2 and 3. For both of connings types an innovative two-way operation mode was created. That allowed for precise operation of the most important controls from a single device. Such functionality is described wider in [1].

Both visualizations are compatible with each other. Every screen was divided into two parts: left one contains all the most important navigational information, divided into six areas, while the right one shows additional information and controls for

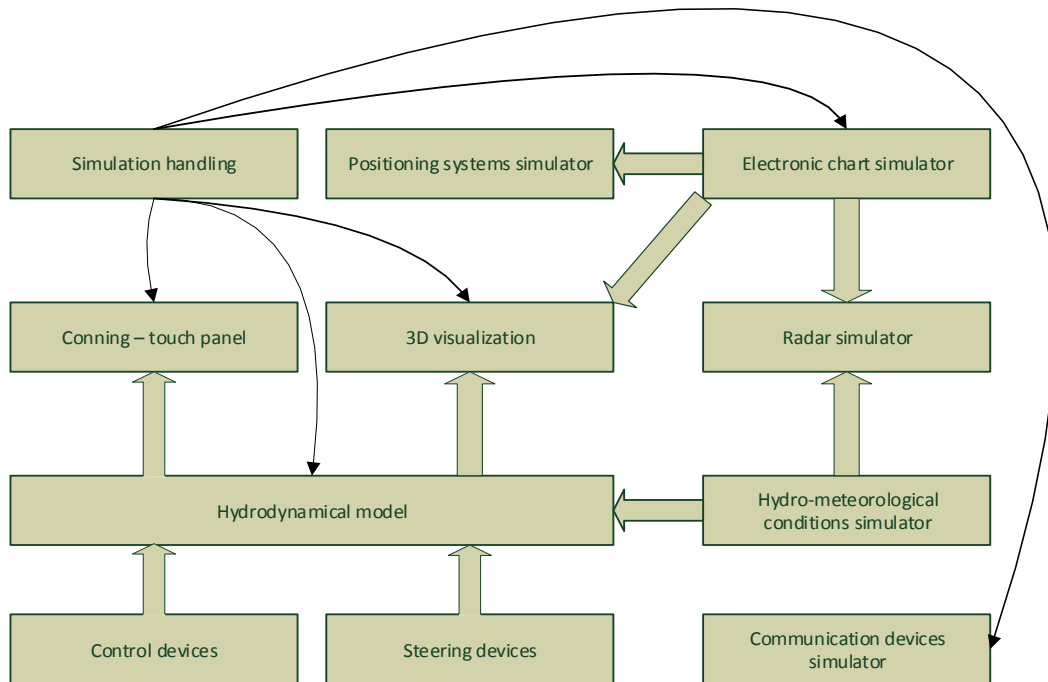


Fig. 1. Simplified block diagram of InSim simulator



Fig. 2. Examples of Astraada touch panel visualizations



Fig. 3. Examples of virtual PC panel visualizations

selected area. Division of whole screen, into seven sub-screens, resulted from dimensions of screen and its purpose. Information, displayed on each small sub-area was connected with one of the six devices and includes:

- DGPS: latitude and longitude, course over ground (COG), speed over ground (SOG), horizontal dilution of precision (HDOP).
- LIGHTS: navigation lights, deck lights and sound signals.
- RELATIVE WIND: wind speed and direction, air temperature.
- CONTROLS: rudder angle, engine command, rate of turn (ROT), thruster command.
- DOPPLER LOG: longitudinal speed, transversal speed, distance.
- ECHO SOUNDER: depth, under keel clearance.

Two interfaces were created for the purpose of communication with both panels:

- TCP/IP based, Modbus protocol, for communication between touch panel and virtual panel;
- MDBD protocol for communication between virtual panel and other devices.

MBDB protocol was created to ensure secure communication between all elements of simulator system, including touch and virtual panels [2]. MDBM's messages are similar to sentences of NMEA protocol, which is used in every navigation device, but are more easily interpreted and protocol itself provides, better controls over single frames and additional measures for detecting bit errors.

An interface for communication with the touch panel was based on Modbus protocol that is widely used in automatic control solutions. It is also advised by the producer – Astraada – to use this specific protocol. As a part of the interface C# software was programmed. Its role is to convert data

from Modbus protocol into MDMB protocol and vice-versa. At the same time it reduces number of calculations, that need to be conducted by the touch panel. Initial tests showed that such calculations were time-consuming, and could shown result in several seconds delays, which is unacceptable in any conning type device.

Another piece of software have to be programmed to allow connection between the manipulators and other devices with USB interface. Three different versions of software were created:

- Direct – for a device connected to data processing CPU;
- Indirect based on UDP protocol – for a device connected to any CPU in a local area network (LAN);
- Indirect based on TCP/IP protocols – for a device connected to any CPU in local area network (LAN).

The direct version is the fastest and easiest in implementation, but is also the least mobile: the device has to be connected at all-times to a computer. Data used by this device is transmitted by UDP protocol. It allows for multiple receivers, which can be both dangerous and error-prone. Such implementation allows for any device to pretend to be the transmitter and does not provide any means for the error correction. Much better solution is to use indirect method based on TCP/IP protocols. Such approach does not have the problems of UDP protocol and requires predefined receivers. Whenever there is a need for change of receivers a change in code or in configuration, file is required. Three types of manipulators were tested during the analysis:

- Engineering simple;
- Engineering advanced;
- Industrial.



Fig. 4. Examples of tested manipulators (engineering simple, engineering advanced and industrial) [http://www.3dconnexion.com/, http://www.chproducts.com]

In addition, the software was created to check the readings of the manipulators. Checked data include:

- a) Id number of the device;
- b) Position of the joystick in six degrees of freedom;
- c) State of buttons.

For the purpose of chart creation and testing, a software coded in C# language was created. Functionality of this software include:

- a) Control over simulation time flow;
- b) Loading of electronic charts;
- c) Adding vessels;
- d) Intuitive edition of position and course of every vessel;
- e) Creation and edition of routes;
- f) Access to navigational information of every simulated vessel;

- g) Plotting GPS data directly from generated text file;
- h) Plotting weather data;
- i) Fast and easy edition of wind speed and direction during simulation.

For the purpose of testing created software, its effectiveness and data integration a set of charts, based on cartographic data, was created. To ensure that edited and prepared charts will be compatible with ECDIS software an open file format was used.

Creation on InSim graphical environment was based on broad analysis of available of the graphic engines. The engine requirements, compatibility with different 3D models and its capabilities with respect to physics simulation, especially hydro-physics and water simulation, were taken into account during comparison. Graphic engine is a part of application code, responsible for real-time

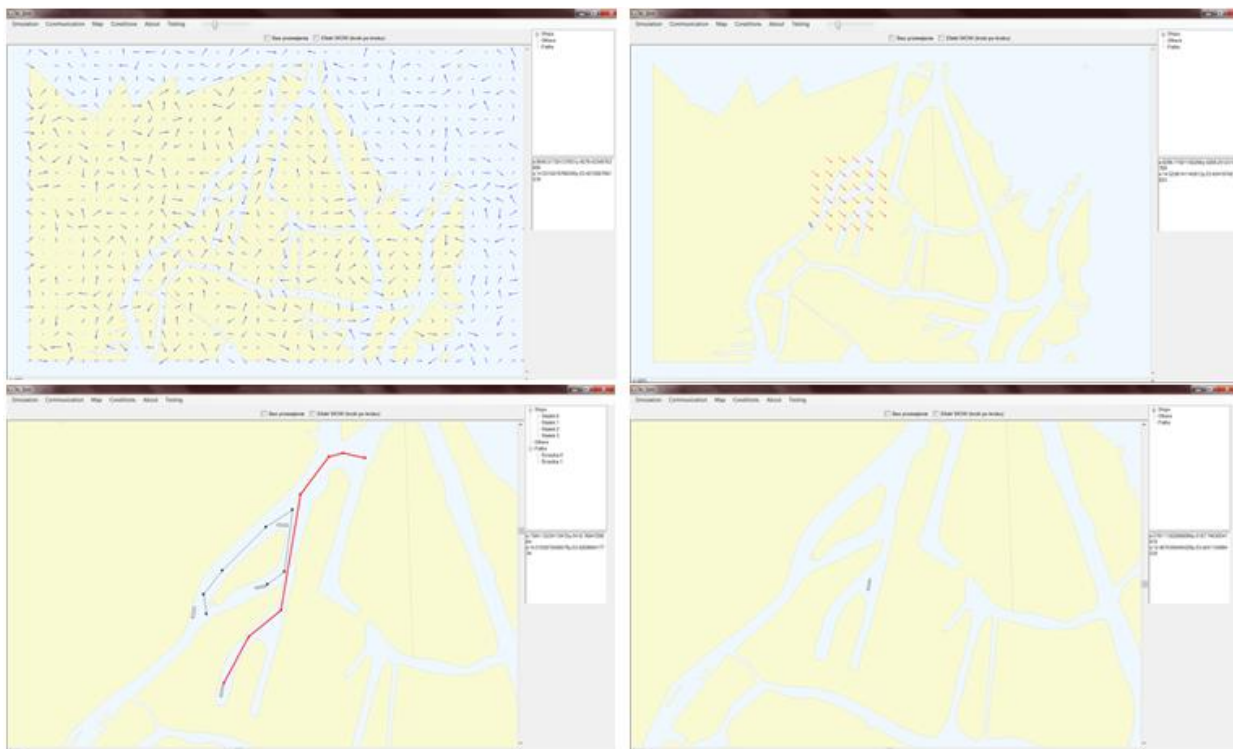


Fig. 5. Examples of navigational information presentation on electronic chart



realization of graphic stream. It contains all elements, necessary to perform complex mathematical calculations and transformation of graphic elements, based on implemented, reliable models, that represent objects and related variables. Following engines were compared:

- a) Adventure Game Studio;
- b) Game Editor;
- c) Game Maker;
- d) Kodu;
- e) Quest3D;
- f) Unity;
- g) Microsoft XNA Game Studio;
- h) RPG Maker;
- i) Multimedia Fusion 2 Developer;
- j) The Games Factory 2;
- k) 3D Game Studio;
- l) DarkBasic 1.13;
- m) Genesis 3D 1.6;
- n) RuneSword 2.5;
- o) Quest Creator;
- p) Raycasting Game Maker;
- q) Cry Engine.

As a result 2, engines were selected: Unity 3D and Quest 3D. Finally Act-3D B.V. Quest 3D 5.0 was chosen as the one to implement in InSim. This choice was based on a better ability of this engine to cooperate with integrated bridge devices (external drivers), ability to modify engine parameters by a programmer and configurable network connections, that can use almost every protocol. Editor environment is almost entirely graphical. Additionally, it was important that application can be edited during its operation. Simulator software was created in Quest 3D by connecting functional blocks called channels. Connected channels create a graph, that represents the graphical stream. Engine “runs” through the graph during every frame of rendering

process, calling out every channel. In this way an interactive 3D application is created. Quest 3D offers newest DirectX capabilities like High Level Shader Language (HLSL) and High Dynamic Range (HDR) lightning, which were used in the simulator.

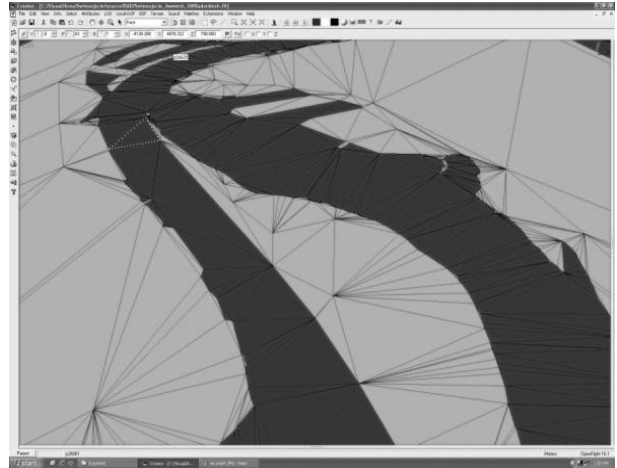


Fig. 6. Example of geometric models used as elements of river area [3]

## Ergonomics

Selection of the equipment, as well as its proper arrangement, that does not restrict operator’s movement, is very important during designing stage. Ergonomic layout of the simulator, provides optimal access to every device. EU directives, Polish Register of Shipping classification society’s regulations and the equipment of existing inland ships were taken into consideration during designing stage.

Arrangement of the wheelhouse was based on Guidance Notes on Ergonomic Design of Navigation Bridge issued by American Bureau of Shipping and on Directive 2006/87/EC of the European



Fig. 7. Examples of inland vessels’ wheelhouse (MS Ursa Montaina i MTS Urgentia)  
[<http://www.hoogendoorn-mbi.nl/projects/?v=2&lid=1&cid=3&tid=10>]

Parliament and of the Council of 12 December 2006 laying down technical requirements for inland waterway vessels. Both documents are describing functionality and construction regulations for navigational bridge and its equipment. Aim of those guidelines is to help in conducting a safe navigation by: providing easier access to all devices, reducing fatigue of the operator and avoiding confusing and misleading situations [4, 5].

### Final remarks

The final result is shown on the figure 8. First tests of simulator confirmed, that graphic visualization, arrangement of devices and ship's dynamic are accurate representation of the real conditions. It was possible partially thanks to maneuvering trials, that were conducted on real inland vessels. These trials covered circulation, zig-zag maneuver and stopping test.



Fig. 8. InSim simulator

InSim equipment covers following devices:

- AIS class B COMAR CSB200;
- AlphaConning – Alpatron;
- Alphapilot- Alpatron – River pilot MF – Mk3 (grey);
- AlphaRadar JMA 610 – Alpatron;
- AlpatronRudderAngleIndicator (RAI) MF 90 (black);
- AMI Marine – model KW8000-BNWS Medium Vessel Standard;
- DSPNOR ScanFaker v. 4 for JRC;
- ICOM IC-M411;
- Intercom LH3000;
- Kobelt – 6511-TP electronic telegraph panel;
- Kobelt – telegraph 6655 double for throttle and thrusters;
- Kobelt steering wheel 7181 FFU 45 deg;
- Nav light switching panel MF – Alpatron;

- QUICK PANEL CE ViewAstrada;
- SIMRAD – IS20 Wind System Package (SimNet / NMEA2000);
- SIMRAD – MX575B DGPS;
- SIMRAD – autopilot AP50;
- SIMRAD IS20 combi;
- SIMRAD IS20 rudder;
- SIMRAD plotter NSE12, antenna 3G;
- SIMRAD RC42;
- Tresco IECDIS – ALPHACHART PLOTTER WITH ANCHOR, AIS, RADAR OVERLAY;
- ZETFON Fonomat.

The simulator, thanks to its accurate representation of reality, will allow for effective training for inland vessels' crewmembers. It will also help in conducting research in any field connected to inland shipping industry. Open structure allows for creation of new areas giving possibility for testing new investment like inland harbors, waterways and hydro-technical installations. Another important feature of InSim is weather control and simulation. Altogether it creates a possibility for testing existing and nonexisting areas in conditions that could normally make a risk for a human life.

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### References

1. BILEWSKI M., GUCMA M., DUCZKOWSKI M.: Consolidating navigational information for inland maneuver simulator purpose. *ExploShip*, Świnoujście 2012.
2. BILEWSKI M., GUCMA M., DUCZKOWSKI M.: MDMB data exchange protocol in inland maneuver simulator. *ExploShip*, Świnoujście 2012.
3. ZALEWSKI P., GRALAK R., TOMCZAK A.: Navigational areas and marine objects modeling methods in contemporary Ship's Bridge Simulator. *Scientific Journals Maritime University of Szczecin* 13, 2008.
4. Guidance Notes on Ergonomic Design of Navigation Bridges. American Bureau of Shipping, 2003.
5. Directive 2006/87/EC of the European Parliament and of the Council of 12 December 2006 laying down technical requirements for inland waterway vessels.

### Other

6. GRALAK R.: Assumptions to the Selective System of Navigational-manouvering Information Presentation. *Transnav Jurnal* 5(4), 2011.