A real-time simulation technique for ship-ship and ship-port interactions

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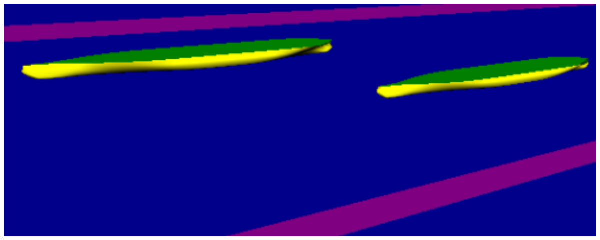
Introduction

Since the early 70's ship maneuvering simulators using fully equipped bridge structures are being used to study the real-time behavior of ships in open water and in ports and to train ships crews to carry out maneuvers safely and efficiently. The number of simulators in use bears testimony to the need for insight in ship behavior and the successes reached in training crews to sail ever larger ships in existing and new ports. Besides training of crew members, simulators are used to judge maneuvering characteristics of new, as yet unbuilt ships, efficiency and safety of new harbours and the effects of new propulsion systems and maneuvering aids. The basic process of a real-time maneuvering simulator is the mathematical model which represents the behaviour of a vessel sailing at variable speeds in deep or shallow water, in current, at high and at low speed without or with the effects of port structures, bottom irregularities and of other ships included. At the present, probably all simulators make use of mathematical models based on Newton's equations of motion for a body moving in the horizontal plane or , in some cases, in all 6 degrees of freedom. Hydrodynamic forces due to flow around the hull, rudder action and variations in propeller speeds are incorporated based on empirical data derived from model tests or from analysis of full scale data. An increasingly important effect on vessel moving in ports is due to ship-ship interactions or ship-port structure interactions, the last being, for instance, bank suction effects where banks can also be submerged structures or local water depth changes. It is common practice to include such effects based on tabulated interaction data derived from model tests or off-line computations using more or less complicated hydrodynamic models ranging from strip-theory-based interaction models to double-body potential flow using panel models or even full-blown CFD computations.

Real time computation of interaction forces

The present contribution concerns the development of a computational procedure for ship-ship and ship-port structure interaction using a double-body potential flow method and its real time application in a maneuvering simulator. The purpose is to be able to dispense with the need to generate interaction data bases and such an approach is expected to increase flexibility with respect to cases studied in the simulator. The method is applicable to multi-body cases involving ships and port structures. The flow equations are solved using standard zero-order panels and Rankine sources with or without the effect of restricted water depth (see ref. 1 and ref.2). A crucial aspect of the application of such computational methods in real time is the computational load, governed by the number of ships, port structure elements and the total number of unknowns (panels) that need to be solved at each time step. Until recently, the only way to directly influence the computation time was to decrease the number of panels in the problem, the lower limit being set by the required accuracy of the computed result. However, in recent years, the advent of inexpensive multi-core computers and parallelization of the codes has brought the possibility of real-time application for practical cases into view. Also a recent development concerns the application of Graphic Processing Units (GPU), originally developed for fast visualization of computer games, for which nowadays compilers are available making it relatively easy to program such codes for processing using these extremely fast and massively parallel devices. Such units are relatively inexpensive and can be added on to existing desk-top units. At present, top-of-the-line consumer units sport 1500 - 3000 parallel computing cores and can be truly called 'massively parallel' computers.

In order to illustrate the developments for the computation of the ship-ship interaction problem, an example is shown in the Figure below. This Figure shows the panel models of a container vessel sailing at 7 kn overtaking a container vessel sailing at 4 kn in a 600 m wide and 8000 m long channel section. The number of panels on each vessel amounted to 828 and 810 respectively and the on the channel sides 5840 panels. The water depth amounted to 19 m.



	Total No. of panels	I7, 1 core s/step	I7, OMP s/step	I7 , GPU s/step
Channel 1	7478	97	9.0	3.2
Channel 2	4558	30	4.5	1.3
Open water	1638	1.3	0.24	0.26

Computations were carried out for the vessels sailing in channel 1 (quays modeled using panels), channel 2 (one side modeled with panels, other quay through mirroring) and in open water for 3 cases: firstly, using a single core of an i7 processor, secondly, applying OpenMP and using all cores of the same i7 processor and lastly, applying a NVIDIA GTX690 GPU (using only one of the two processors on the board) attached to the i7 processor. The average time to compute each time step are given in the table. These results show that for the open water case even the single i7 core gives acceptable results. Applying OMP and the GPU result in about the same time per step. For the case of the vessels sailing in the channel considerable differences occur with the single core giving unacceptably long computation time. Applying OMP reduces the time considerably while the GPU results are again significantly lower. The question is what is an acceptable refresh rate? This depends, for instance, on the time scale of the maneuvers. An overtaking maneuver takes considerably more time, with lower rate of change of the forces, than a meeting maneuver, the former allowing a lower refresh rate than the latter. Careful study will determine which refresh rates are acceptable for real time simulation of maneuvering vessels.

The total number of panels on the ships and the port geometry is of great influence on the computational costs. Careful modeling of the port structures will be essential in order to achieve acceptable time step costs since it appears that computation times for the ship-ship interactions without presence of port structures are already useful. The particular case of a channel could also be modeled by double symmetry . The total number of panels would remain at 1638 and the computational costs reduced accordingly with some additional overheads for the mirroring operation. We have chosen to use panels to model the channel sides since in real cases the double symmetry technique would not always be applicable due to the irregular shape of real port geometries or due to sloping banks. In the presentation more details of the computational procedure will be given as well as correlations between computed and measured interaction forces.

Application in real time simulator

The real time simulator at MARIN uses a modular type mathematical maneuvering model. This means that total forces acting on ships are divided into different modules like hull forces, propeller forces, rudder forces and their interactions, environmental forces (caused by wind, wave, current), bank suction forces, ship-ship interaction forces, tug forces etc. Traditionally, bank suction and ship-ship interaction forces were calculated at every time step by interpolation from a predefined force database. Now, at every time step, these forces are calculated using a software developed by PMH called 'Delpass' here onwards. This software is running on a separate PC (called Delpass computer) to avoid influencing the real time simulation processes. The coupling of Delpass with MARIN's real time simulator is described in the flowchart below. The Delpass computer, an i7-based machine, was running the OMP-version of the code. Before the start of simulations, Delpass reads one time inputs from an input file (called 'manforc.inp'). This file contains information like number and names of data files to be used in the computations (containing panel description of concerned ship and port structures), water depth etc. At every time step, Delpass reads velocity and position of all concerned structures from another input file (called 'moton.inp'). Delpass receiver updates motion.inp file every time simulator sends new velocity and position values (using simulator sender). Using data from these two input files (motions.inp and manforc.inp), Delpass calculates interaction forces and moments at every time step for the current relative position and velocity of concerned structures and writes them into an output file (called 'force.out'). Delpass sender passes this data to simulator receiver every time the output file is updated. Finally the simulator software receives interaction forces and moments through this receiver, adds them to total ship forces, solves the motion equations for the next time step and passes the results (new velocity and position values) to Delpass receiver using the simulator sender. This cycle is repeated at every time step to account for the effect of ship-ship or ship-port interaction in real-time. It should be noted that there are various time steps involved in the whole cycle (Delpass calculation time step, Simulator calculation time step, Simulator sender time step and Simulator receiver time step). Our analysis shows that simulator sender and receiver time steps can influence the interaction force results, hence care must be taken while deciding their values.

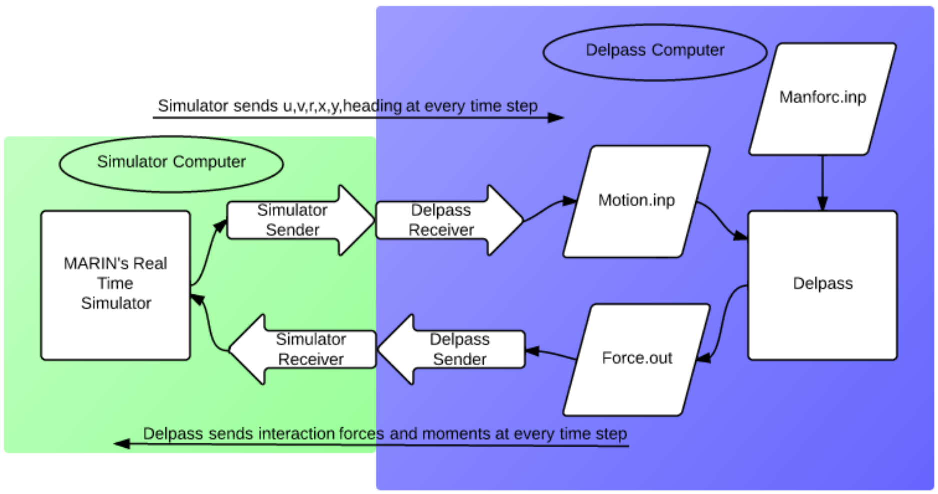


Figure: Flowchart detailing the coupling of Delpass with MARIN's real time simulator

Several cases have been tested with coupled Delpass at MARIN. In one test case, a Car Carrier is overtaking a Qmax LNG Carrier in Eemshaven fairway. The principle particulars of ships and number of panels on all the three structures are given in table below.

	Length (L_{PP})	Breadth (B)	Draught (T)	Displacement	Block Coefficient (C_b)	No. of Panels
Units	[m]	[m]	[m]	[m^3]	[-]	[-]
Car Carrier	225.0	32.2	9.0	42926.5	0.658	794
QMax LNG Carrier	345.0	55.0	12.0	167089	0.734	892
Eemshaven fairway	-	-	-	-	-	1010

The speeds at which the two ships were sailing and the distance between them is described in table below:

Ships	Velocity (kn)	Distance between ships (m)
Car Carrier	15	50
QMax LNG	9	

Note that both the ships were made very heavy during the run so that their trajectory is not influenced by the interaction forces. Hence both ships move in a straight line. This was done because the results from standalone Delpass for a similar run were available to make a comparison (the plot below shows the comparison, OD = online Delpass, SD = standalone Delpass). In the presentation more test results will be discussed.

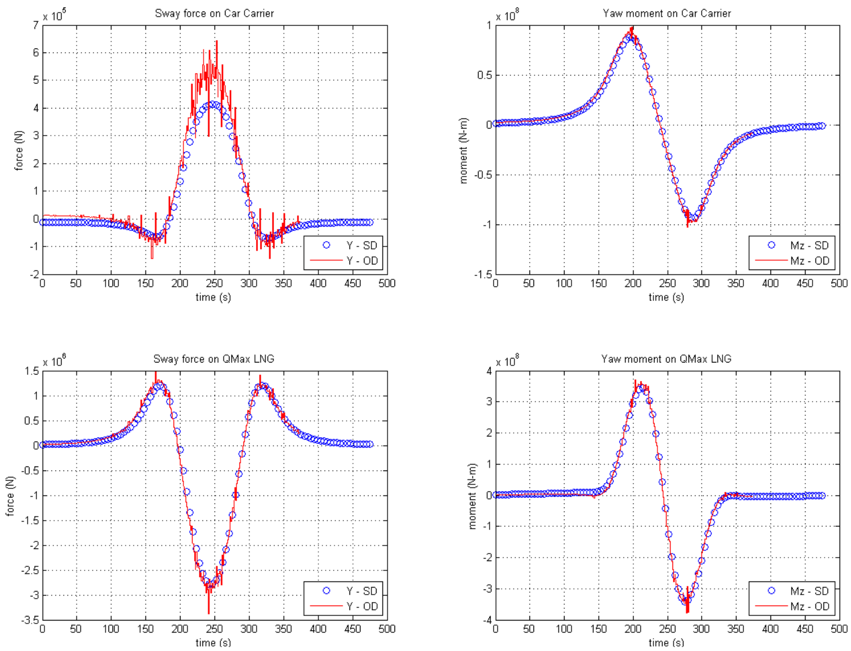


Figure: Interaction forces on Car Carrier and QMax from standalone and coupled Delpass

To obtain the results shown above, the simulator calculation time step was 0.2 s, the simulator sender time step was 1.3 s, the simulator receiver time step was 0.7 sec and the Delpass calculation time step varied from 0.6 to 1.3 s.

Conclusions

Delpass is a significant add-on to MARIN’s real time maneuvering simulator. As it has been observed from various tests conducted at MARIN with coupled Delpass, the interaction forces calculated in real time are quite reliable. Implementing Delpass in a real time simulator reduces effort that was initially needed to create interaction forces databases and provides more flexibility to user in training scenarios where interaction forces play an important part. A real time simulator coupled with Delpass provides its users the freedom to simulate wider range of distances and speeds between passing structures.

Future Work

The GPU version of Delpass can be coupled with simulator for bulkier cases. This has not been tested at the moment. At present, Delpass assumes constant water depth. This feature can be enhanced in future to account for interaction forces caused due to changing bathymetry.

Acknowledgement

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References

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