A Wave Model for Simulating Vessel Effecting Shallow-Water Waves in Real-Time

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Since the advent of high order computation and computer graphics, simulations of real world phenomena have taken to contribute in many areas. **Simulations** have two different branches. One focuses on producing results that is perceptively closer to the real-world scenario whilst the objective of the other is to provide results that are numerically precise. For simulations that are solely user-experience centered, the focus is to achieve perceptively realistic output *[Ex: Movies, PC/Console Games]*. But, for scenarios where the simulation output is used for predictive decision making and for subsequent simulations, accurate results are expected. Whilst there are a lot of research done (and ongoing) towards trying to achieve both, the challenge lies in achieving them it **Real-Time**. An important area of such simulations is the field of Oceanography. Given the complexity of the models required to produce accurate numerical simulations, the challenge of achieving real-time results have become increasingly difficult. The closer the model is towards accuracy, the higher the time taken for execution. Hence many of the accurate models can only yield results in non-real-time whereas the others have their own drawbacks. The more specific **shallow-water waves** are generated as a result of this energy being conducted to the shore from the deep ocean waves.

We propose a novel solution to simulate vessel effecting shallow water waves in real-time for usage in maritime training simulators. The solution is based on the Navier-Stokes (NS-E) equations that describe the motion of fluids. The NS-E is derived from the continuity equation describing the conservation of mass and the conservation of momentum theory on 3 directions. Thus, the usage of NS-E produces the most accurate numerical results over other equations (Boussinesq Equ$^{\underline{n}}$, Green-Naghdi Equ$^{\underline{n}}$). By depth integrating the NS-E the resulting depth averaged equations are used to solve for wave heights in shallow water surfaces.

We use the open source CFD software package OpenFOAM in our solution. The depth averaged NS-E, which is solved via the PIMPLE algorithm gives the output of the height fields of the waves over the simulation area considered. Naturally, the NS solver is computationally expensive and takes quiet a lot of time to produce results. Compromising on the algorithm, which solves the equations to reduce time, would affect the accuracy of the expected results. Hence, our approach focuses on restricting the simulation area to only that which has an effect on the vessel to achieve the results in real-time. The rest of the shallow water surfaces are simulated using a less expensive solver. When a boundary of entry into a depth effective shallow water area is identified, the velocity fields at that boundary, generated by the wave model in the deep ocean are calculated. These values are set as the boundary conditions to the shallow water wave model. The boundary is continuously updated with calculated values from the deep ocean model. The area of simulation based on this solver is restricted to only an area in which the waves have an effect on the vessel. If this area is fully submersed within a shallow topography, then the boundary condition is calculated by the distance of the boundary from the last point of Deep Ocean. Also the change in the water depth from the vessel to the edge of the simulation area in the direction of the shore is calculated. If this change is insignificant then the depth of the simulation area is set to an averaged constant. If a considerable gradient is identified, then the simulation area is divided into a set of averaged discrete depth levels.

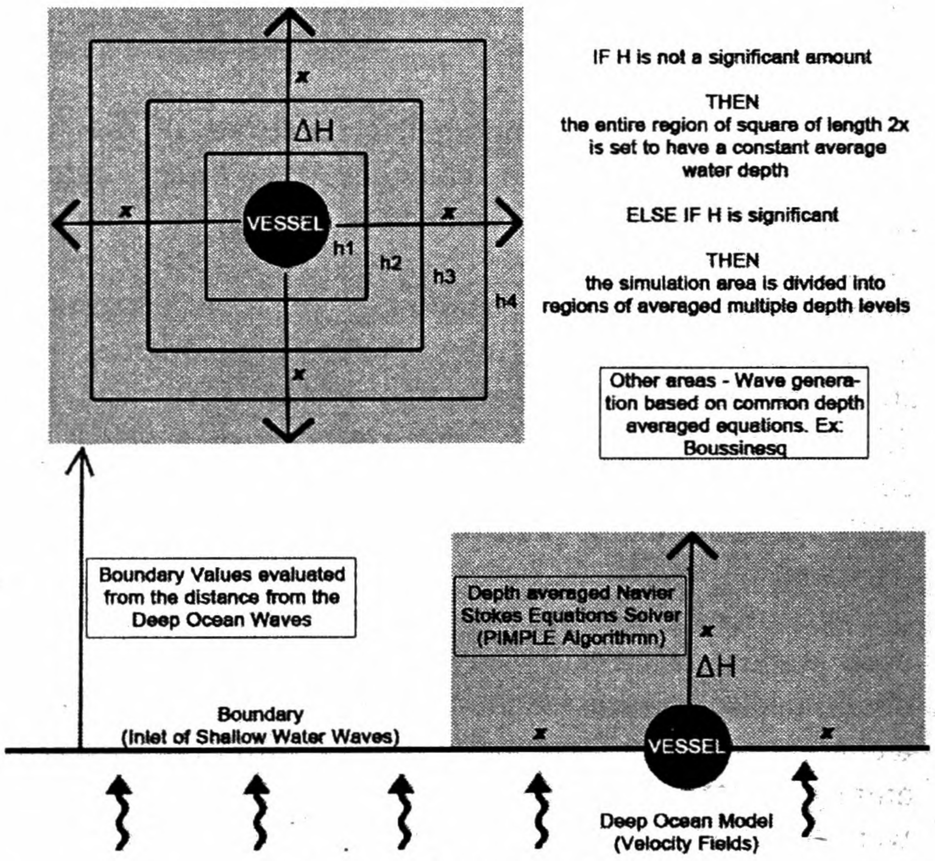

Figure 1: System Design

Finally, we have proposed a novel solution to solve accurate fluid motion equations in real-time that provide precise results for wave parameters in depth effective shallow waters. This is a research work focusing on integration into a maritime training environment.