Application of Artificial Neural Networks to Simulate Tsunami Propagation in Model Basins
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ABSTRACT
In this study, the method solving the differential governing equations of the 3D tsunami numerical model is proposed: the differential equation solver with artificial neural networks (ANNs). As a preliminary study, the present proposed method is applied to tsunami propagation on three kinds of model basins: a flat bottom basin, a uniform slope basin, and a basin with sea hill. The present proposed method after training shows good performance for some cases of tsunami propagation on these model basins.

KEY WORDS: Artificial neural network; numerical model; tsunami propagation; time integration.

INTRODUCTION
Tsunamis propagating offshore are as extreme long waves and the effect of vertical acceleration in those flow can be neglected. Those tsunamis, therefore, can be simulated by horizontally two-dimensional numerical models with the hydrostatic pressure assumption. On the other hand, the flow of tsunamis around structures such as breakwaters is complex, which is three-dimensional with non-hydrostatic feature because the effect of vertical acceleration cannot be neglected. To simulate complex tsunami flow around such structures, it is necessary to use three-dimensional non-hydrostatic models. However, the run time of simulation with those 3D models is much longer than that with those 2D models because 3D models need smaller grid size and shorter time interval.

To design port structures such as breakwaters and to decide the layout of those structures in ports, it is necessary to conduct many cases of simulation with different structural types and/or different layouts by using one of those 3D models through trial and error. Regarding calculation cost, 3D models may not be efficient for the structure design and the layout design because of the much longer run time.

Artificial neural networks (ANNs) are numerical information processing systems, which are simply modeled on information processing of human brain. There are some kinds of ANNs, which are categorized according to their network structures: layered ANNs, and interconnected ANNs. ANNs have been applied to various problems in various fields. In coastal engineering filed, for example, ANNs have been applied to the following: tsunami height prediction at coast by tsunami information observed offshore (Mase, Yasuda and Mori, 2011), stability analysis of rubble-mound breakwaters by information of waves and structures (Mase, Sakamoto and Sakai, 1995), estimation of wave height distribution in harbor by offshore wave condition (Londhe SN and Deo MC, 2004) etc.

Honda (2016) proposed new method solving the differential governing equations of the 3D tsunami numerical model with an ANN. As a preliminary study, this differential equation solver with an ANN was applied to tsunami on the model basin with a flat bottom and shows good performance for simulation of the flow velocity and the pressure. However, the verification validation was not for time integration of tsunami propagation but for each time interval in every time step. The accumulation of error should be evaluated because the solver with an ANN may not satisfy a mass conservation law of incompressible fluid.

In this study, the similar of differential governing equation solver with an ANN of Honda (2016) is modified to satisfy a mass conservation law, and both solvers are applied to time integration of tsunami propagation on three kinds of model basins: a flat bottom basin, a uniform slope basin, and a basin with sea hill.

ALTERNATIVE SOLVER WITH ANN

ANN
Feedforward three-layered neural network was employed in the study of Honda (2016) because the training process of the networks is relatively simple.

Fig. 1 shows the diagram of a feedforward three-layered network: input layer, hidden layer, and output layer. All the layers have artificial models of human neurons which are called as units (Fig. 2). In this network, each of units in the input layer has only one input signal and only one output signal. On the other hand, each of units in the hidden layer and the output layer has lots of input signals and only one output signal. Each unit in a