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Modeling Nonlinear Water Waves in a Numerical Wave Tank Using Localized RBF-DQ Method

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Abstract:

In this paper, the problem of propagation of nonlinear water waves in 2D numerical wave tank is numerically solved by RBF-DQ method which is a novel meshless method. The local form of RBF-DQ is used to improve the performance of the method in terms of the computational cost and applicability. Mixed Eulerian- Lagrangian method is utilized to calculate free surface potential velocity and elevation which is the most important part of the simulation. Fourth order Adams-Bashforth-Moulton scheme is applied for time stepping integration. For verification of the results analytical and available numerical solutions are used.

1-Introduction:

Nonlinear water waves propagation is an important phenomenon in the field of costal and ocean engineering. Therefore, several researches have been performed in this area. A major group of these researches are based on mesh-based methods. Grilli et al. [1] used boundary element method to solve the nonlinear differential equations of free surface flow. Zhang et al. [2] simulated the propagation of nonlinear water waves in a numerical tank using desingularized boundary integral method. Longuet-Higgings and Cokelet [3], Ohayama and Nadaoka [4], Issacon [5], Dommermuth and Yue [6] used boundary element method to simulate nonlinear water waves. Although these methods provide accurate and acceptable results, they are time consuming and expensive due to the mesh generation process. This is true particularly for the problem of modeling free surface where the mesh must be updated frequently.

Recently, meshless methods, a new generation of numerical methods has been developed. These methods are based on randomly scattered nodes and can overcome the drawbacks of mesh-based methods. Ma [7] simulated the propagation of nonlinear water waves in a numerical tank using meshless Petrov-Galerkin method. Darlymple and Rogers [8] presented a meshless SPH model for simulation of nonlinear waves. Senturk [9] used meshless RBF method to solve the nonlinear wave equations.

RBF-DQ is a meshless numerical method which is based on the essence of differential quadrature (DQ). Using small number of nodes, DQ method provides very accurate results. But the method cannot directly be applied to problems with irregular boundaries. To overcome this problem, radial basis functions can be used as the shape function of DQ method.

In this paper, local form of RBF-DQ is used to extend the scope of its application and reduce the computational costs. Local RBF-DQ estimates the function derivatives at a node by a linear weighted combination of the functional values at its neighboring nodes.