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Numerical approximation of acoustic equation using radial basis function-discontinuous Galerkin method

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Abstract

Acoustic equation is an important equation in order to determine wave propagation in a medium. The Application of acoustic equations vastly known, i.e. elastic wave propagation, fluid dynamics and gas dynamics equivalent. This paper present *Radial Basis Function-Discontinuous Galerkin Method* (RBF-DGM) in order to solve acoustic equation. RBF-DGM method is a numerical method, proposed to solve partial differential equations (PDE). RBF-DGM approximated the space domain with RBF and using DGM for time integration method. RBF-DGM application presented then in order to solve acoustic equation. The numerical of RBF-DGM presented, and compared with analytical solution as a result. The numerical results, show that the RBF-DGM (linear) predicting the exact results or analytical well.

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Keywords: RadialBasis Function; Discontinuous Galerkin Method; Numerical Method; Acoustic wave

1. Introduction

Acoustic equation is an important equation in order to determine wave propagation in a medium. The form itself is a second order of partial differential equation (PDE). The Application of acoustic equations vastly known, i.e. elastic wave propagation, fluid dynamics and gas dynamics equivalent [1]. In some case, the acoustic equation has analytical or exact solution, but in fact, analytical solutions not easily found in daily life, so the numerical method is

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the main tool to solve these equations. Recently the mesh-based numerical methods that require the creation of grid or mesh is a popular method and has developed well. Some alternative numerical method that is not based on a mesh or mesh-less or mesh-free lately gained popularity but still in the early stages and is very open for further research. Numerical methods based on creating mesh, for example Finite Difference Method (FDM), Finite Element Method (FEM) and Finite Volume Method (FVM). Examples of meshfree methods are Element Free Galerkin (EFG), Reproducing Kernel Particle Method (RKPM), Smoothed Particle Hydrodynamics (SPH), Radial Basis Function (RBF). Meshless method has the advantage compared to the mesh-based method, which does not require the creation of mesh on the domain, thus making meshless method to be simpler. In addition meshless method is suitable in problems involving changes in the geometry domain, because it does not need an effort mesh back (remeshing) on the domain.

FDM method is a method based on grid or mesh-based numerical method. This method is simple, the earliest used, and is still used in many different areas of science and engineering recently. This method is simple, because it is formulated directly from the calculus [2]. FDM method can be used directly on the governing equations of a problem. Otherwise, difficulties found in order to solve problems with complex geometries and boundaries.

FEM in the other hand, a numerical method using variation methods or the weighted residual method (MWR) to create weakform of governing equations. Weakform subsequently used to approximate the existing problem. FEM method based on sub domains or elements on the domain, so the method is included in the mesh-based method [3]. This method has the advantage compared to the FDM to solve complex geometry. This method is very widely applied in various fields of science and engineering. Lately discontinuous Galerkin Method (DGM) introduced, this method is derived from FEM. DGM method has the advantage that the higher order accuracy, *hp*-adaptivity, has semidiscrete scheme and has a good performance for the simulation that has discontinuity [4].

FVM method, a grid based method that divides the domain into a cell and the integration is performed on each cell. Integration performed on each cell for evaluation flux entering and leaving the cell, as a conserve quantity. This method is very popular in computational fluid dynamics (CFD).

EFG method is a meshless method, which uses a weak form of the governing equations and moving least square (MLS) in the shape function [5]. EFG method offers the ability to create domain without mesh of domain. EFG method offers the ability to solve the problem without creating a mesh of domain. Background mesh is still required to perform the integration of the weak form. Application of the EFG is a problem of elastostatic and propagation crack.

RBF method firstly applied to solve the data interpolation on scattered data. RBF has also applied in solving PDE numerically. RBF is a numerical method based on meshless using collocation principles on governing equations. The advantages of RBF is accurate, simple and truly meshless, without using background mesh. RBF produce a high condition number of and full system matrix [6].

Numerical solution of the time domain is very important in order to get an accurate response of the model. Generally, integration worked with explicit fourth order of Runge Kutta method, Newmark-β, HHT- α, Wilson-θ etc [7]. Some numerical methods based or grid-based mesh combined with time integration to solve the problem of PDE numerically on the space and time domain. Explicit methods generally require time increment, Δt is small enough, such that a stable simulation achieved. By using a small Δt conductlong enough simulation or long runtime. Therefore, faster and more stable integration time required to solve with, for example implicit method. One of the implicit methods for the integration time is DGM.

This paper presented numerically solving acoustic equation. Solving conducted by combining the method of RBF and DGM. Completion conducted by combining the method of RBF and DGM, well known as RBF-DGM, combining both methods with partial discretization [3]. The RBF method for solving the space domain used is for the ease and accuracy reason. Time integration are selected using DGM because of implicit and stability behavior. Combining these two methods produce a simple, accurate and stable calculation.

2. Method

Acoustic equation in two dimensions shown in Eq. 1, where p is the independent variable that will be calculated, c is a constant, t time and x, y space domain.