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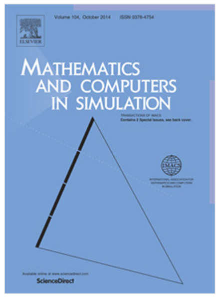

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Efficient implementation of energy conservation for higher order finite elements with variational integrators

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Abstract

In this paper, we introduce a variational integrator for higher order finite element models. The solution quality of finite element simulation strongly depends on the approximation in time and space. A variational integrator is robust due to conservation of both the balance of total linear momentum and the balance of total angular momentum. It also binds the error in the balance of total energy. We extend the variational integrator to an integrator that conserves the balance of total energy as well. However, the approximation in time cannot mend the approximation error in space. Therefore, we use a higher order approximation in space to obtain a better solution compared to the real live model that should be simulated. We show different numerical examples with DIRICHLET and NEUMANN boundaries. For the DIRICHLET boundaries we use the LAGRANGE multiplier method and for the NEUMANN boundaries we introduce the forces on the nodes by constant pressure.

Keywords: energy conservation, variational integrator, higher order finite elements, time integration schemes

1. Introduction

The dynamic solution of simulations for solid mechanics depends on two important parts. The first part is the discretization in space and the second part is the discretization in time. Usually, the discretization in space will be done with linear elements like hexahedral elements or tetrahedral elements, but the convergence in space for these elements can be very slow. It means in effect that a lot of elements are needed to calculate a solution that is exact enough. This effect, can be based on locking, is well known in the long history of the Finite-Element-Method. Locking can be classify in geometric and material locking. An example for geometric locking is shear locking which is determined by the aspect ratio of the element. The second category, material locking is volumetric locking where the compression module represents the critical parameter. In [1] a criterion was shown for determining the suitability of finite elements, with the result that higher order elements are more suitable. For elements up to cubic order this is shown in [2]. This constitutes a substantial requirement of computational time to solve the problem. Therefore, we increase the approximation order for elements to get a better and faster convergence in space. This is often implemented for static simulations.

In this paper we apply these elements to dynamic simulations, up to a cubic approximation order in space [3, 4] in order to avoid the volumetric locking effect. For the realization of boundary conditions either in the form of fixed nodes or fixed directions at nodes we use the LAGRANGE multiplier method. In contrast to boundary conditions for contact problems we use a strict node boundary without a approximation in space

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