A stable, implicit time integration scheme for Discrete Element Method and contact problems in dynamics

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ABSTRACT

The field of applications for Discrete Element Method (DEM) is constantly growing, enabling the simulation of granular matter. However state of the art integration schemes are mostly adopted from other methods, which results in certain drawbacks in either performance and/or accuracy. The most common time integration schemes in Discrete Element Method are explicit algorithms, e.g. Verlet, which are conditionally stable, only [1]. Their critical time steps, calculated from the highest eigen frequency of the system, reach step sizes of $[10^{-7},10^{-8}]$ s easily. If high frequency vibrations are not of interest for the application, the low time step sizes result in an immense restriction of performance.

Attempts to use implicit schemes usually require evaluation of the right hand side of the equations of motion, i.e. a complete reevaluation of the neighborhood search and contact forces within predictor-corrector iterations [2]. This is especially expensive if several corrector steps are needed to reach convergence. Given the non-smooth forces originally A-stable integrators are conditionally stable only for application in contact dynamics. However the critical time step can be chosen dependent on the particle size and the highest velocity in the system. Thus the time step size can usually be chosen to be several orders of magnitudes higher than those of explicit schemes.

Both, implicit and explicit schemes are most suitable for simulations of rapid flows. However, given that high-frequency oscillations are not important for the results' accuracy, in many applications like soil modelling [3], computational efficiency is sacrificed for simulations of dense granular matter in both cases. The algorithm presented in this paper aims to improve the computational efficiency while mostly maintaining accuracy as well as the higher critical step size of implicit integration schemes.

Thus it is implemented as a predictor-corrector scheme using a prediction of the forces, without evaluating the right hand side, in order to have an implicit estimate for the next time step. This force prediction is specially designed to meet the requirements of the non-smooth forces present in DEM and contact dynamics. Due to the estimation of the forces, both corrector and predictor can be implemented to be implicit.

It will be shown, that the developed technique enables to speed up particle simulation while using considerably higher time steps without noticeably sacrificing accuracy. The usage of the algorithm and the correspondent time step control are shown in example problems. Thereby the stability will be tested for different contact models with respect to the conservation of energy. In order to verify the algorithm, the Newmark-ß integration scheme is used as the reference to compare the performance and accuracy.

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