Activation of constraints at position and velocity levels in the nonsmooth generalized-α method

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This talk addresses the simulation of mechanical systems including rigid and flexible bodies, kinematic joints and frictionless contact conditions. The condition of impenetrability of the bodies in contact is expressed as a unilateral constraint, with the consequence that impacts and/or instantaneous changes in the velocities may arise in the dynamic response.

Time-stepping methods, such as the Moreau–Jean scheme, are extensively applied as the solution to such nonsmooth system models. A fundamental property of the Moreau–Jean scheme is that the unilateral constraints are imposed at velocity level. The consequence is that some penetration can be observed in the numerical solution, which may not be physically acceptable.

In order to prevent such penetration problems, this talk presents an algorithm which enforces the constraint not only at velocity level, so as to inherit good consistency and stability properties, but also at position level. For that purpose, the Gear-Gupta-Leimkuhler (GGL) approach is generalized to systems with unilateral constraints following a similar idea as in [1, 2]. However, the present work differs from [1, 2] by the formulation of specific complementarity conditions at position and velocity levels, as well as by the construction of an implicit algorithm which solves the dynamic equilibrium and the complementarity conditions in a monolithic way using a semi-smooth Newton process at each time step. The method relies on an activation criterion, which is evaluated at every iteration of the Newton process and leads to the simultaneous satisfaction of the unilateral constraints at position and velocity levels [3].

In order to improve the solution when flexible bodies are present, we also follow the strategy proposed in [4], which involves a partitioning of the generalized forces in the dynamic equilibrium into smooth terms and nonsmooth (impulsive) terms. All impulsive terms are treated using a first-order Euler implicit integration scheme to ensure consistency but the smooth terms are integrated using the second-order generalized-α method. The advantage of this approach is that the energy behavior is strongly improved compared to the Moreau–Jean scheme, especially for mechanical systems exhibiting both impacts and structural vibrations.

References

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