Application of Nonsmooth Dynamics to Rockfall Protection Ring Net Simulation

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Abstract. The simulation of rockfall protection ring nets with rocks of arbitrary convex shape poses a challenging task. One major aspect hereby is the formulation of the net-rock interaction. We approach this problem by using nonsmooth contact dynamics with hard unilateral constraints, as this allows our model to describe impacts as well as frictional contact. The net is modeled as a discrete multibody system using a finite number of material points. To take into account the influence of rock shape, the rock is modeled as rigid body with the shape of an arbitrary convex polytope. For each material point a frictional contact law with the rock model is formulated.

Introduction

In alpine regions large rocks, often significantly heavier than one ton, pose a great threat for humans and infrastructure if they become loose and fall downwards. One possibility to prevent damage is the use of rockfall protection ring nets which are able to capture rocks with a kinetic energy up to $11\,000\,\mathrm{kJ}$. The extremely high impact forces, which such a net has to endure, necessitate extensive testing in the terrain or on test sites. Due to practical reasons, only a limited number of tests under very specific conditions can be conducted. Numerical simulations are used to obtain insight for more general test cases. The state-of-the-art in rockfall net simulation uses purely spherical rock shapes and neglect friction.

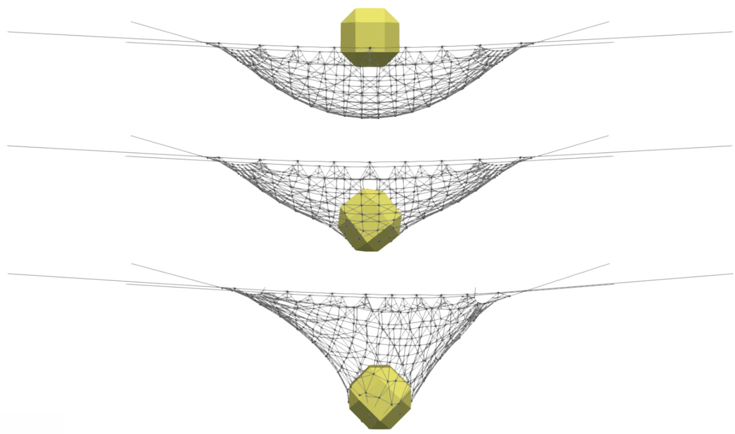

Figure 1: Snapshots of simulation result with rotating $EOTA_{111}$ norm block as rock model.

Simulation with set-valued frictional contact laws

The approach taken here models the rock as an arbitrary convex polytope and uses the nonsmooth contact dynamics method to take set-valued frictional contact laws into account. The discrete net model of [1] is employed for the net itself, whereas hard unilateral contact with Coulomb friction is added between rock and net. For numerical simulations, we used Moreau's timestepping scheme [2], which directly discretizes the measure differential inclusion

$$\mathbf{M}\mathrm{d}\mathbf{u} - \mathbf{h}(\mathbf{q},\mathbf{u})\mathrm{d}t = \mathbf{W}(\mathbf{q})\mathrm{d}\mathbf{P}$$
$$+ \text{ normal cone inclusions for } \mathrm{d}\mathbf{P}\,,$$

capturing the system dynamics. Special attention is paid to the efficient calculation of contact distances between the rings of the net and the rock. Current research focuses on incorporation of cables in the model to accommodate for the sliding of the rings over the cables, which causes the so-called curtain effect.

References

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[2] R. Leine and N. Wouw, van de, eds., *Stability and convergence of mechanical systems with unilateral constraints*. Lecture Notes in Applied and Computational Mechanics, Germany: Springer, 2008.