Simulation of rockfall using the non-smooth contact dynamics approach

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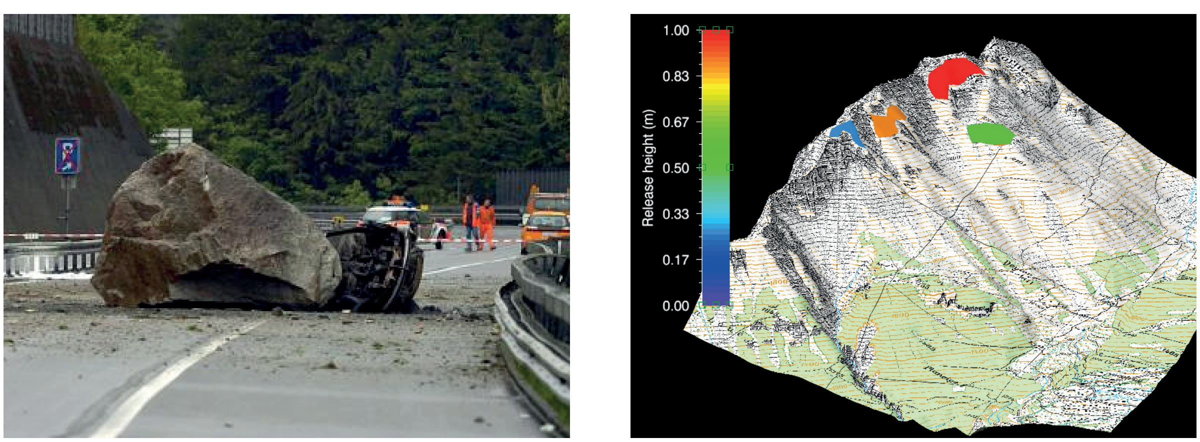
Introduction

In this project we intend to develop numerical methods as well as a software code for the simulation of three-dimensional motion of polygonized objects with frictional unilateral contacts. These methods will be tailored for and applied to the simulation of rockfall run-out lengths. This project is a collaboration between the Center of Mechanics at the ETH Zurich and the Swiss Institute for Forest Snow and Landscape Research (WSL/SLF).
Rockfall is a serious problem in mountainous areas and represents a threat to mankind and infrastructure (see Figure 1(a)). The WSL/SLF develops the simulation package RAMMS (Rapid Mass Movement System) with which danger maps of hazardous areas can be computed. These danger maps are used to make decisions on protective measures such as nets and galleries. The software RAMMS allows its user to define the rockfall release areas as shown in Figure 1(b) directly on a selected portion of a landscape map. A multitude of simulations are run with slightly varying statistically distributed initial conditions, thereby creating a statistic danger map. Previous simulation modules all used point-mass models in combination with a penalty approach.
The Center of Mechanics is developing a 3D simulation module for the simulation of polygonized rigid rocks on a tesselated slope by using the non-smooth contact dynamics approach [1, 3, 4]. This simulation module is currently being integrated into the RAMMS software.

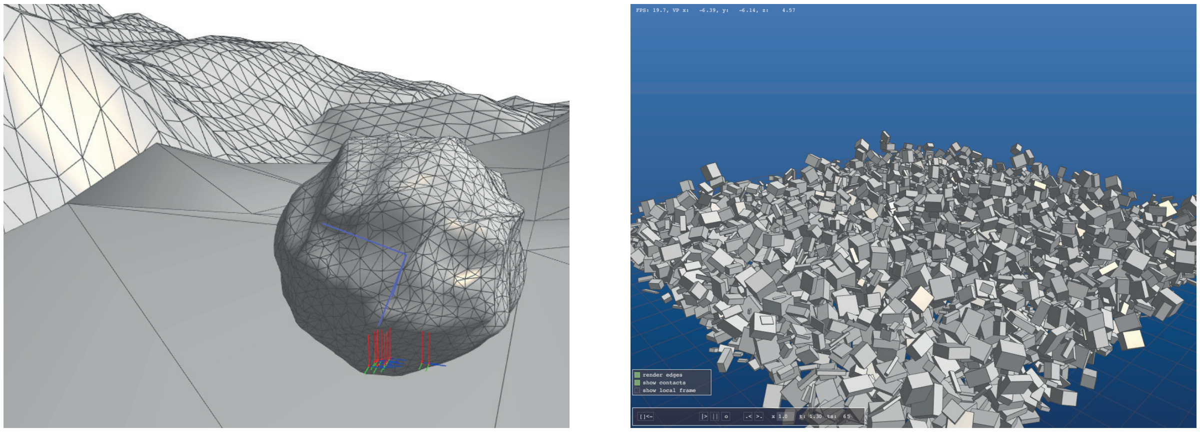
Simulation Approach

The simulation model describes the rock geometry using three dimensional convex polytopes. The full three dimensional simulation of rockfall allows to study the influence of rock geometry on the run-out lengths and the scattering of the trajectories. The terrain geometry is obtained from GIS-data and described by a height-map. The rock is assumed to be an indestructible rigid body with constant mass distribution.
Moreau's time-stepping method is used for the numerical time-integration. The contact problem in each timestep is solved by a Gauss-Seidel iteration method [2]. The contact points are found by ray-casting the vertices of the rock polytope onto the bilinearly interpolated height-map. The contact geometry between rock and landscape is modelled as a finite collection of discrete contact points. The contact model is a combination of Signorini's law, Coulomb friction law and a (generalized) Newton-type impact law. Other sources of dissipation, such as rolling friction and the interaction with forests, are currently being neglected.
An OpenGL 3D visualization tool has been developed to allow for direct inspection of the running simulation (Figure 2(a)). The simulation module has been developed in C++ and is connected to RAMMS using an XML interface.



(a) (b)

Figure 1: (a) Car hit by a big rock. (b) Rockfall release areas are marked by colors in the graphical user interface of RAMMS.



(a) (b)

Figure 2: (a) A single rock approximated with triangles. (b) Simulation of 4000 cuboids.

Conclusions & Outlook

Comparisons with real rockfall data gathered by WSL/SLF have been made and indicate that the model is overestimating the run-out lengths. Other dissipative mechanisms, such as rolling friction and rock-forest interactions, should therefore be taken into account. Another problem is that the Gauss Seidel iteration is slowed down by linearly dependent generalized force directions which result from the presence of multiple contact points. A technique to reduce the number of contacts has to be developed.

Future research will focus on the simulation of a large number of rigid polygonized bodies which may come into contact with each other (see Figure 2(b)). Porting the Alart-Curnier method to the GPU will therefore be an important next step. Furthermore, we plan to use the method and code to study nonlinear phenomena of granular materials, e.g. the stability of oscillons. Finally, these type of large-scale granular simulations may be of interest to the WSL/SLF in simulating and understanding the dynamics of avalanches.

Acknowledgement

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