Data-Driven Mechanics Laboratory

Master thesis / Semester project

Digital twin simulation of rockfall hazards

Description: Rockfalls remain a major natural hazard in Alpine regions, frequently threatening infrastructure and transportation corridors, and causing significant financial impacts each year (Fig. 1 a). This project aims to develop a digital twin framework for simulating and assessing rockfall hazards in real-world terrains. Using terrain reconstruction (e.g., from available drone photogrammetry or LiDAR datasets - Fig. 1 b [1]) and rock geometry characterization, the student will build virtual replicas of actual slopes and surrounding protection systems. The rockfall trajectories will be simulated using our in-house Discrete Element Method (DEM) code, capturing realistic dynamical behavior including impacts and interactions with flexible or rigid barriers. By leveraging the digital twin, the project will explore uncertainty quantification techniques — assessing how variability in rock properties and terrain roughness affects runout distance and energy dissipation - as well as machine learning surrogate models, enabling rapid risk mapping and probabilistic prediction of rockfalls. The project bridges computational particle mechanics, data-driven modeling, and natural hazard assessment, contributing toward smart, data-informed design and mitigation strategies for rockfall-prone regions.

Prerequisites:

- Background in computational mechanics
- Strong coding skills (C++, Python)

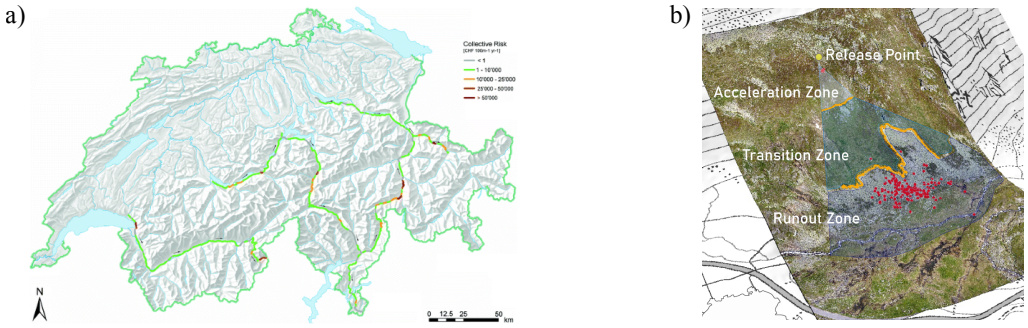

Figure 1: a) Map of risk hot spots on the Swiss national road network (source: Swiss Federal Office for the Environment). b) Overview of the rockfall test site Chant Sura in the Flüelapass (reproduced from [1]).

References

[1] Andrin Caviezel, Sophia Demmel, Yves Bühler, Adrian Ringenbach, Marc Christen, and Perry Bartelt. Induced Rockfall Dataset 2 (Chant Sura Experimental Campaign), Flüelapass, Grisons, Switzerland, 2020.

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