Data-Driven Mechanics Laboratory

Master thesis

Accelerating geophysical flow simulation using machine learning

Description: Geophysical flows such as landslides, rockfalls, and snow avalanches pose significant risks in Switzerland (Fig. 1). High-fidelity simulations of these phenomena are essential for hazard assessment and early warning systems. However, traditional physics-based numerical simulations on complex 3D terrains are computationally intensive, which restricts their use in time-critical applications and large-scale risk analysis. The objective of this project is to accelerate geophysical flow simulations by leveraging modern machine learning techniques, including purely data-driven and physics-informed approaches. The final outcome is the development of surrogate models that approximate the outputs of physics-based simulations with high accuracy but at a fraction of the computational cost. In the first step, a dataset of high-resolution geophysical flow simulations (e.g., MPM or DEM) on 3D terrains, potentially enhanced with real-world observational data, will be compiled and preprocessed. Next, the machine learning model will be implemented and trained to predict the dynamics of the flows. The trained surrogate model will be evaluated in terms of its ability to reproduce simulation outputs such as velocity fields, runout distances, and deposition patterns on unseen terrains. The project will be supervised jointly with the Chair of Alpine Mass Movements at ETH Zürich.

Prerequisites:

- Background in numerical modeling
- Strong coding skills (Python, C++)

a) b)

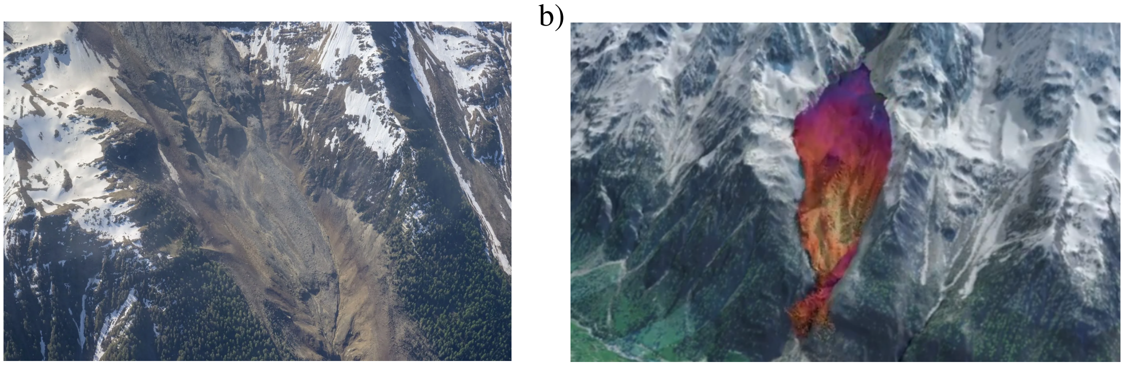

Figure 1: a) The May 2025 landslide in Blatten, Switzerland (Credit: Swiss Federal Office of Topography), and b) an MPM simulation of the landslide (Credit: Chair of Alpine Mass Movements, D-BAUG ETHZ).

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