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Benchmark rock fall hazard assessment and safety concept for touristically developed alpine gorges (Höllentalklamm, Bavarian Alps).

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The Höllentalklamm (Höllental Gorge) in Grainau is part of the main mountaineering route to the Zugspitze and with up to 2000 daily visitors a major tourist attraction in the Bavarian Alps. Following several recent rock fall events (up to 300 m³) the TU Munich collaborates with the local Alpine Club (DAV-GAP) to detect, assess and monitor rock fall hazards and to develop a benchmark safety concept for the Höllentalklamm. We combine multi-temporal terrestrial laser scanning, field mapping and the use of wireless sensor networks and evaluate the applicability of these methods for deeply incised alpine gorges.

In this study, we investigate a deeply incised and tectonically shaped alpine gorge in a well-researched mountain range (Wetterstein). In visibly accessible areas, multi-temporal terrestrial laser scanning is applied to (a) detect active rock fall areas, (b) identify hazardous objects pre-failure and (c) monitor potentially unstable parts of the rock face. Additionally, larger objects, such as a 600 m³ rock tower located directly above the track, are equipped with a redundant crackmeter system implemented in a wireless sensor network. Together with the DAV Garmisch-Partenkirchen, we are working on the development of safety procedures and the implementation of an automated early warning system. The first results show that terrestrial laser scanning is well-suited to detect post- and pre-failure rock falls above the level of detection, however, monitoring of small deformations remains a challenge. The crackmeters provide sub-millimetre deformation data of the rock tower and show generally stable conditions but a significant sensitivity towards external triggers such snow blasting in spring. Aside from that, direct rock fall hits hinder the sensor maintainace.

Here we show a benchmark rock fall hazard assessment and safety concept for Alpine gorges with high safety demands providing four years of data. This work helps to evaluate the applicability of well-established monitoring techniques in confined and inaccessible terrain (deeply incised gorges).

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