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# Lower cost fixed installation photogrammetry rockfall monitoring

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Fixed installation remote rockfall monitoring offers the opportunity to observe the behaviour of rock slopes in high spatial and temporal detail. Fixed installation automated Terrestrial Laser Scanning (TLS) systems, for example, have been used to monitor rockfall precursor behaviour and rockfall magnitude frequency at thirty-minute scan intervals (Kromer et al. 2017; Williams et al. 2018). In both cases, these monitoring approaches resulted in a highly detailed view of slope behaviour, which is crucial for improved management of rockfall hazard.
In this study, a fixed installation monitoring system was developed using a fixed array of cameras. The goals were to develop a lower cost alternative to fixed TLS systems, to investigate the feasibility of this approach to monitor rockfalls, and to investigate the long-term behaviour of a rock slope with high temporal detail. A target slope was chosen along Interstate 70, 50 km west of Denver, Colorado within the Rocky Mountains. A five-camera fixed system was installed 80 m from the slope from the opposite side of the valley covering a slope area 50 m in width and 30 m in height. Each camera is contained within a protective housing and is powered by solar panels and batteries. The cameras are triggered twice daily and upload the pictures automatically to a server at the Colorado School of Mines. The camera system has been operational since April 2018.
An automated data processing pipeline was developed using Structure from Motion (SfM) photogrammetry software and in-house change detection software. The change detection software uses a TLS target scan of the slope for scale and registration. As a check, the registration method was compared with a target-based method using fifteen targets installed on the slope and surveyed using a total station. The change detection algorithm calculates change to date, monthly change, and daily change. The daily change results are used in an algorithm that detects individual rockfalls events, clusters them, and measures their volume.
The system achieved a 0.025 m detection limit using a 95% confidence threshold. Over an 8-month period, over 100 rockfalls were detected in the range of range of 0.003 to 0.04 m3. Continued work is being conducted to investigate the feasibility of this approach using other distance to slope and camera-lens configurations. This fixed camera approach is feasible for long-term hazard monitoring, can be used to better understand mechanisms and processes of hazards, and can potentially be used as part of an early warning system.

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