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Optimizing visual coverage - a case study for webcam-based monitoring for landslide alert

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Landslides and debris flows pose a hazard to people and infrastructure in mountainous regions of the Earth. Regional authorities require landslide-monitoring systems that support their landslide risk management. Earth Observation (EO) has proven to be useful in mapping landslides for landslide inventories that enable a better preparedness. Additionally, dynamic development also happens for close-range sensors on the ground, like webcams with a relatively low cost. The combination of webcams into sensor networks provides an opportunity for the development of landslide monitoring systems with very fast response times so that they qualify for landslide alert. However, the potential area coverage that a specific webcam constellation can achieve needs to be better understood, an issue that can be investigated with visibility analysis tools in combination with mathematical optimization approaches. Throughout the past decades, the optimization of visibility analysis has gained broad acceptance as research field in various disciplines such as landscape planning, urban planning, telecommunication network planning and archaeology. However, the use of visibility models for optimizing the constellation of a webcam-based landslide monitoring system has rarely been studied. Major objective of the research is to find a heuristic greedy algorithm for siting observers in terrain to maximize visual coverage using visibility analysis.

We develop an according analysis model for maximizing the visual coverage of webcams and performed two case studies for landslide and debris flow monitoring. In light of recent natural disaster events, the study area of Taxenbach, Salzburg, Austria, an inner-alpine region, was selected to test the model's validity. Primary input data is a landslide susceptibility map for limiting the area of interest (AOI), where monitoring is required and recommended. For an accuracy assessment, records from the historic landslide inventory database were available as reference points. The results of the landslide monitoring case show that a set of ten viewpoints selected by the algorithm for webcam locations cover around 75% of the AOI. Nevertheless, more than 60% of all reference landslide records are located within the hazard zone and lie in the coverage area of the observer points. For the debris flow monitoring case, the visual coverage that the algorithm provided for a buffer area around an extracted stream network in the study area is slightly lower because only 62% of the area-of-interest can be seen from the locations selected by the algorithm. Accuracy assessment reveals that only 1/3 of the torrent stream network runs through visible terrain parts.

It can be concluded that the adjusted model works fast and straightforward and guarantees the determination of a feasible webcam monitoring network. Results confirm that a greedy algorithm can only approximate to optimal solutions. Still, the approach and its resulting information are useful as a planning basis for further monitoring campaigns. It can be noted, however, that a constellation of ten webcams is probably too low for large-scale landslide and debris flow monitoring. A more suitable application case may be the investigation of a smaller AOI around a small set of selected mass movements using high resolution terrain models.