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# Automated crevasse mapping: assisting with mountain and glacier hazard assessment

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Glacial environments are used by many for recreation (climbing, skiing) and are acknowledged as presenting hazards including bad weather, rock and snow avalanches and the presence of crevasses. While predictions are available for weather and avalanche potential, crevasse location is often only communicated by word of mouth, is based on experience, or requires some understanding of glacier dynamics. We present an automated detection method for identifying crevasses in remotely-sensed imagery which can be used to assist in the management and reduction of exposure of risk in these environments.

Many countries, including those within the European Alps, Scandinavia and in Iceland, have dedicated search and rescue teams ready to provide assistance when required as a result of these hazards. However, these services are expensive to run and have a huge area to cover and furthermore, due to the nature of the glacier environment not all situations can be successfully managed. In Iceland, the Icelandic search and rescue service (www.icesar.com and www.safetravel.is) provided crevasse maps for the main glaciers. With the rapid rate of change of glaciers, including periodic glacier surges, the subsequent changes in the location of crevasses requires such maps to be updated on a regular basis which can be time-consuming if done manually.

We present a method that provides a first pass identification of crevasse features from a wide variety of remotely sensed images (including optical, hyperspectral, LiDAR and others) which can then be assessed and validated by location experts to quickly update crevasse maps. Our method uses a Fourier Transform approach, identifying linear features from an image of the glacier surface, from which aggregate crevasse feature spacing and orientation are derived. The Python code behind the method is open source and freely available (http://doi.org/10.5281/zenodo.830251). We show examples of the method's application using 5x5 and 2x2 m LiDAR digital elevation models of the Hofsjökull ice cap in central Iceland and compare the results with manually-produced existing crevasse maps of the same areas.

Mapping crevasse locations provides information which can be disseminated to identify 'no-go areas' for those working in and enjoying these environments. Furthermore, within the scientific community, the ability to map crevasses – as well as identify their spacing and orientation – offers the opportunity to assess glacier evolution through time and provides insights into glacier dynamics.