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Robust snow avalanche detection using machine learning on infrasonic array data

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Snow avalanches may threaten people and infrastructure in mountain areas. Automated detection of avalanche activity would be highly desirable, in particular during times of poor visibility, to improve hazard assessment, but also to monitor the effectiveness of avalanche control by explosives. In the past, a variety of remote sensing techniques and instruments for the automated detection of avalanche activity have been reported, which are based on radio waves (radar), seismic signals (geophone), optical signals (imaging sensor) or infrasonic signals (microphone). Optical imagery enables to assess avalanche activity with very high spatial resolution, however it is strongly weather dependent. Radar and geophone-based detection typically provide robust avalanche detection for all weather conditions, but are very limited in the size of the monitoring area. On the other hand, due to the long propagation distance of infrasound through air, the monitoring area of infrasonic sensors can cover a large territory using a single sensor (or an array). In addition, they are by far more cost effective than radars or optical imaging systems. Unfortunately, the reliability of infrasonic sensor systems has so far been rather low due to the strong variation of ambient noise (e.g. wind) causing a high false alarm rate. We analyzed the data collected by a low-cost infrasonic array system consisting of four sensors for the automated detection of avalanche activity at Lavin in the eastern Swiss Alps. A comparably large array aperture ($\sim$350m) allows highly accurate time delay estimations of signals which arrive at different times at the sensors, enabling precise source localization. An array of four sensors is sufficient for the time resolved source localization of signals in full 3D space, which is an excellent method to anticipate true avalanche activity. Robust avalanche detection is then achieved by using machine learning methods such as support vector machines. The system is initially trained by using characteristic data features from known avalanche and non-avalanche events. Data features are obtained from output signals of the source localization algorithm or from Fourier or time domain processing and support the learning phase of the system. A significantly improved detection rate as well as a reduction of the false alarm rate was achieved compared to previous approaches.