Automatic identification of alpine mass movements based on seismic and infrasound signals.

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Introduction

Alpine mass movement processes emits characteristically seismic and acoustic waves in the low frequency range and so this events can be detected and identified based on this signals. Several approaches for detection systems based on seismic or infrasound signals has already been developed, but a combination of both methods, which can increase detection probability and reduce false alarms is currently used very rarely.

So this work presents an approach for a detection and identification system based on a combination of seismic and infrasound sensors. The system is based on one infrasound sensor and one geophone which are placed co-located and a microcontroller where a specially designed detection algorithm is executed, which can detect mass movements in real time directly at the sensor site. Further this work tries to get out more information from the seismic and infrasound spectrum produced by different sediment related mass movements to identify the process type and estimate the magnitude of the event.

System Setup

Infrasound Sensor:

- Chaparral Model 24
  Sensitivity 2 V/Pa,
  Frequency range 0,1-100 Hz
- MK-224
  Sensitivity 50 mV/Pa,
  Frequency range 3-200 Hz
- Electret Condenser Micophone KEC
  Sensitivity -42±3 dB,
  Frequency range -20-20000 Hz

Geophon:

- Sercel SG-5
  Sensitivity 80 V/m/s,
  Natural frequency 5 Hz
- Sensor NI SM-6/H-A
  Sensitivity 28 V/m/s,
  Natural frequency 4,5 Hz

Microcontroller:

Signal analyses and data-logger
- Luminary LM3S8962:
  50 MHz ARM Cortex-M3 Processor
  4 ADC-Channels – 100 Samples/s
  Data recording on MicroSD-Card
  (16 GB: >4 months)
  User-Interface (display, keys),
  Ethernet , UART, GPIOs

Communication and Output:

- Alarm Output (2 Levels)
- Time Synchronisation
  Timeserver (Ethernet or GSM-Module)
  GPS
- Status-Messages and E-Mail Alert
- Webserver (Remote Control)
  Ethernet
  GSM-Module

Detection Method

The developed detection algorithm analyses the evolution in time of the frequency content from the infrasonic and seismic mass movement signals. Therefore different frequency bands are used to analyse the infrasound signal, whereby a 3 to 15 Hz band characterises debris flows and a 15 to 45 Hz band is used for debris floods. For the seismic signals a frequency band from 10 to 30 Hz is used for both event types.

Three different criteria has to be fulfilled for the Detection-Time T_{det} (20 s) to identify events:

- The average infrasound and seismic amplitudes of the debris flow/debris flood frequency bands have to exceed a certain threshold (to distinguish between different event sizes, two limits are used: Level 1 (L1) and Level 2 (L2)).
- The average infrasound amplitudes of the debris flow/debris flood frequency bands has to be at least the half of the average amplitude of the frequency band below (to avoid false alarms due to wind).
- The variance of the seismic and infrasound amplitudes have to be under a certain limit (to avoid false alarms from artificial sources)

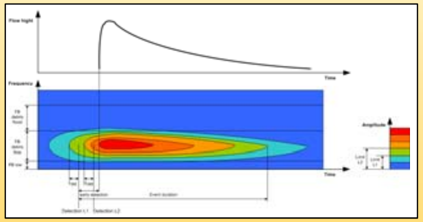
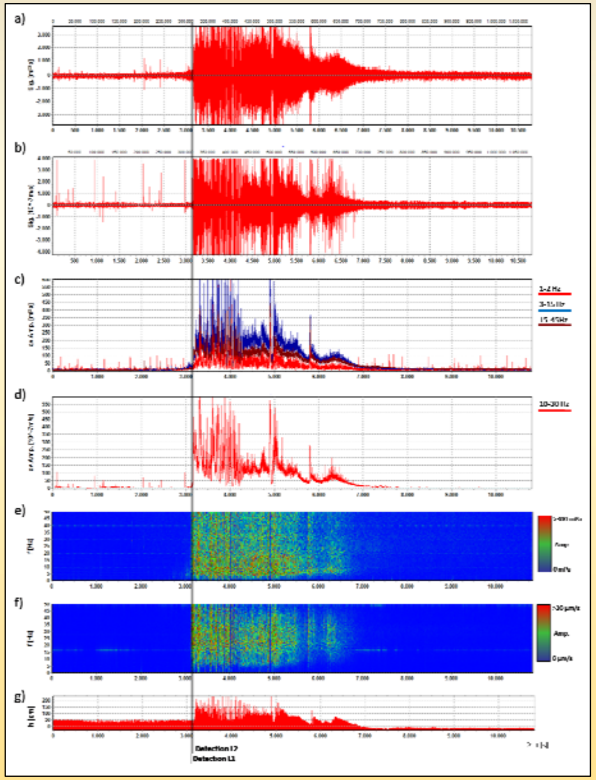


Illustration of an event detection depicted in a running spectrum of a debris flow infrasound signal

Detection Example

This example shows the seismic and infrasound signal of a debris flow at Lattenbach (catchment area 5,3 km²), a test site located in Tyrol and operated by the Institute of Mountain Risk Engineering. This debris flow at Lattenbach was recorded on 10.09.2016 with a peak discharge of 175 m³/s, a total volume of 70.000 m³ and a total duration of 3000 s.

Test site Lattenbach: catchment area and monitoring stations



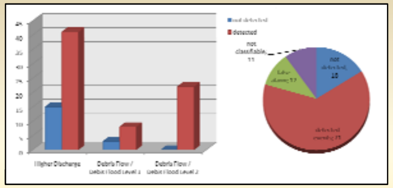
Infrasound and seismic data of the debris flow monitored at the Lattenbach test site on 10.09.2016. Signals are represented with a common base of time. (a) Infrasound time series; (b) Seismogram; (c) Average amplitude of the three frequency bands of the infrasound signal; (d) Average amplitude of the frequency band of the seismic signal; (e) Running spectrum of the infrasound signal; (f) Running spectrum of the seismic signal; (g) Flow height; Lines: time of first detection based on infrasound and seismic data for Level 1 and Level 2.

The event was detected by the detection algorithm at sec. 3162 for Level 1 and at 3176 s for Level 2. So the time between detection and passing of the first surge at the sensor site (at 3180) was 18 s for Level 1 and 4 s for Level 2. The maximum infrasound amplitudes were around 1800 mPa at 12 Hz and the maximum seismic amplitudes of 185 µm/s occurred at 25 Hz.

Results and Discussion

The map below shows an overview of the currently equipped test sites. Data and further information of the test sites are available at:

http://ian-infrasonic.boku.ac.at/



This diagrams compares the event detections, missed events and false alarms at all test sites since 2013. Most of the events from 2013 to 2016 were higher discharge processes (41) whereat 15 events couldn't be detected. Since most of the not detected events in this class were rather small, a detection of this events is not necessary required in opposition for the debris flow and debris flood events. This processes have to be detected and almost all 22 Level 2 events have been detected and also nearly all Level 1 events could be detected (8 out of 11). During the whole operation time of 76.300 h only 12 false alarms at Level 1 and no false alarm at Level 2 were registered and 11 detections couldn't clearly be classified.

The diagrams below shows an approach to identify the magnitude of an event. In this approach we use the maximum infrasound or seismic amplitude to estimate the peak discharge and the sum of the infrasound or seismic amplitudes during the event duration to estimate the total volume of the process. The diagrams is based on Level 2 events recorded at Lattenbach, Farstrinne, Illgraben und Gadria.

This analyses shows that for both, peak discharge as well as the total volume, the infrasound amplitudes with a polygon curve fitting offers the best approach with a R² of 0,901 for peak discharge and 0,936 for the total volume.

This research is just at the begin and further data of different events will be necessary to develop a robust method for a magnitude identification.