# X-Sense II

MEMS ACOUSTIC DETECTORS FOR NATURAL HAZARD WARNING SYSTEMS

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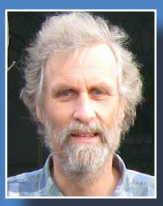

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**What it's about…**

***Developing novel sensing, processing and communication systems for detecting destructive processes such as a rock face collapsing, leading to severe natural hazards.***

**Context and project goals**

X-Sense II contributes to the reduction of this growing gap between supply and demand by technological development and scientific advance. It investigates a complete data chain from custom designed sensor technology over networking, data-based storage and processing towards new discoveries in environmental sciences and new, more effective technologies for early warning.

Steep bedrock in high-alpine regions such as the European Alps is influenced by seasonal frost or permafrost. Knowledge of processes and factors affecting slope instability is essential for detecting and monitoring potentially hazardous slopes. In the attempt to understand or anticipate movement, a combination of differing sensed variables and sensing modalities is usually employed. This includes displacement (GPS, crack meters), seismic/acoustic signals, repeat imagery, and environmental data such as temperatures, precipitation etc.

The current state of the art in sensing systems is based on continuous oversampling and subsequent filtering of the digital data acquired to extract meaningful information. The significant power and data rates associated to important modalities such as GPS and acoustic emission inherently

- necessitate heavy infrastructure in the field for energy harvesting,
- require large amount of data to be stored and communicated and
- impose the difficulty to differentiate signals relevance from the noise generated by other phenomena.

This big data problem effectively constitutes a showstopper with respect to wide applicability.

X-Sense II will follow a new path by exploiting advances in MEMS technology to achieve a trigger-based duty-cycling of complex sensing systems by monitoring acoustic events. This partial relocation of signal analysis and decision-making from the computing domain to the sensor itself will enable close to zero standby-power. The sensing device will be based on a new class of mechanical switches which is highly sensitive and frequency selective. The potential of such an approach is huge and will be explored in X-Sense II: Use the triggering signal to wake up other types of sensor at the same or other locations as well as using the detailed frequency-dependent triggering information as a new modeling input for geoscientific investigations and early warning. This new approach needs scientific advances in MEMS sensor design as well as event-based sensing architectures, adaptive communication and distributed control. In addition, it will only be successful if based on a close interaction between engineering sciences, geosciences, industry and public stakeholders. The analysis of comprehensive acoustic field measurements will provide a characterization of the signals to be used as triggers. The multi-scale approach of X-Sense II, which combines various sensing modalities, is a key factor of success. Measuring displacement with crack meters in rock faces and with continuous GPS on more gentle slopes, is a proxy for the high-magnitude low-frequency hazards under investigation because cumulatively, it can lead to slope failure.

**How it differentiates from similar projects in the field**

The current state of the art in sensing systems is based on continuous oversampling and subsequent filtering of the digital data acquired to extract meaningful information. The significant power and data rates associated to important modalities such as GPS and acoustic emission inherently

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- impose the difficulty to differentiate signals relevance from the noise generated by other phenomena.

## Quick summary of the project status

The current state of the art in sensing systems is based on the principle of continuous oversampling and subsequent filtering of the digital data acquired to extract meaningful information describing the processes to be observed.

X-Sense II is exploiting advances in MEMS technology to achieve a trigger-based duty-cycling of complex sensing systems by monitoring acoustic events. This partial relocation of signal analysis and decision-making from the computing domain to the sensor itself will enable close to zero standby-power. The sensing device will be based on a new class of mechanical switches which is highly sensitive and frequency selective. The potential of such an approach is huge and will be explored in X-Sense II: Use the triggering signal to wake up other types of sensor at the same or other locations as well as using the detailed frequency-dependent triggering information as a new modeling input for geoscientific investigations and early warning.

## Success stories

The field site for pilot experiments has been identified and pilot deployments of acoustic and micro-seismic measurements undertaken and have been analyzed.

Successful launch of the PERMOS Continuous GPS Pilot Program as a result of the technology transfer of the GPS sensors system developed in X-Sense to authorities and other research groups.

In collaboration with the cantonal and federal authorities, as well as other research groups at ETH Zurich X-Sense developed sensor technology and data evaluation methodology has been applied to a number of natural hazard sites in Valais, Switzerland.

A number of publications involving members of different groups have been achieved. This shows the active interdisciplinary collaboration in X-Sense II.

**Presence in the media:**

Agnes Fazekas: *Am Puls der Gletscher*. Natur - Das Magazin für Natur, Umwelt und besseres Leben., Februar 2014.

Agnes Fazekas: *Das Knacken der Alpen*. Spiegel Online, Januar 2014.

Christian Thiele: *Auf Allen Gipfeln ist Not*. GQ Magazin, Condé Nast Verlag GmbH, München, December 2013.

Philipp Imboden, Jan Beutel: Servicearbeiten am Hörnligrat ausgeführt. Air Zermatt online Newsticker, January 2015.

Claudia Langenegger: 'Die Bergdoktoren', Migros-Magazin, Nr. 42, Oktober 2014.

Radio Rottu über öffentlicher Vortrag von Samuel Weber in Brig im Nov 2014.

**Patent**

"Mechanical Transducer for the Detection of Acoustic and/or Seismic Signals" M. Müller, V. Maiwald, C. Roman, C. Hierold. The invention comprises a mechanical amplification mechanism for the detection of acoustic and seismic signals based on a coupled mass network.

## Main publications


Dominic Ruefenacht, Matthew Brown, Jan Beutel and Sabine Suesstrunk, Temporally Consistent Snow Cover Estimation from Noisy, Irregularly Sampled Measurements, VISAPP, Lisbon, Portugal, January 2014.

B. Buchli, F. Sutton, J. Beutel, L. Thiele, Towards Enabling Long-Term Performance Guarantees For Solar Energy Harvesting Embedded System. , Proc. 11th European Conference on Wireless Sensor Networks (EWSN 2014), Oxford, UK, February 2014.

Felix Sutton, Reto Da Forno, Roman Lim, Marco Zimmerling and Lothar Thiele, Demonstration Abstract: Automatic Speech Recognition for Resource-Constrained Embedded Systems, Proceedings of IPSN 2014, Berlin, April 2014.

B. Buchli, P. Kumar, L. Thiele, Optimal Power Management With Guaranteed Minimum Energy Utilization For Solar Energy Harvesting Systems, 2015 International Conference on Distributed Computing in Sensor Systems, Fortaleza, Brazil, June, 2015.

Roman Lim, Marco Zimmerling and Lothar Thiele, Passive, Privacy-preserving Real-time Counting of Unmodified Smartphones via ZigBee Interference, Proceedings of the 11th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Fortaleza, Brazil, June 2015.

Felix Jonathan Oppermann, Carlo Alberto Boano, Marco Zimmerling and and Kay Römer, Poster Abstract: Automatic Configuration of Controlled Interference Experiments in Sensornet Testbeds, Proceedings of the 12th ACM Conference on Embedded Networked Sensor Systems (SenSys), Memphis, TN, USA, November 2014.

David Hasenfratz, Olga Saukh, Christoph Walser, Christoph Hueglin, Martin Fierz, Tabita Arn, Jan Beutel and Lothar Thiele, Deriving High-Resolution Urban Air Pollution Maps Using Mobile Sensor Nodes, Pervasive and Mobile Computing Volume 16, Part B, January 2015, Pages 268–285.

Felix Sutton, Reto Da Forno, Marco Zimmerling, Roman Lim, Tonio Gsell, Federico Ferrari, Jan Beutel and and Lothar Thiele, Poster Abstract: Predictable Wireless Embedded Platforms, Proceedings of the 14th International Conference on Information Processing in Sensor Networks (IPSN), Seattle, USA, April 2015.

Felix Sutton and Lothar Thiele, Poster Abstract: Wake-up Flooding: An Asynchronous Network Flooding Primitive, Proceedings of the 14th International Conference on Information Processing in Sensor Networks (IPSN), Seattle, USA, April 2015.

Faillettaz J., Or D., Effects of signal attenuation in natural media on interpretation of acoustic emissions in the context early warning systems, Geophysical Research Abstracts, EGU General Assembly 2014, Vol. 17, EGU2015-9017, April 2015.

Faillettaz J., Or D., Failure criterion for materials with spatially correlated mechanical properties, PHYSICAL REVIEW E 91, 032134 (2015).

M. Müller, V. Maiwald, M. Käch, C. Hierold, C. Roman, A passive micromechanical broadband amplifier for acoustic emission sensing (Conference Proceedings), Proceedings of the 18th International Conference on Solid-State Sensors, Actuators and Microsystems (Transducers 2015), Anchorage, USA, July 2015.

Wirz V, Geertsema M, Gruber S, Purves , Temporal variability of diverse mountain permafrost slope movements derived from multi-year daily GPS data., Wirz V; Geertsema M; Gruber S; Purves, RS (2015): Temporal variability of diverse mountain permafrost slope movements derived from multi-year daily GPS data, Mattertal, Switzerland. Landslides: 1-17. DOI: 10.1007/s10346-014-0544-3.

B. Buchli, F. Sutton, J. Beutel, L. Thiele, Dynamic Power Management for Long-Term Energy Neutral Operation of Solar Energy Harvesting Systems, Proceedings of the 12th ACM Conference on Embedded Networked Sensor Systems (SenSys), Memphis, TN, USA, November 2014.