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Master Thesis Project
For
xxx

Supervisor: Jan Beutel, Andreas Biri

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End Date: tbd

Detecting Ambient Vibration Patterns using Multiple Sensors

The PermaSense project develops, deploys and operates wireless sensing systems customized for long-term autonomous operation in high-mountain environments. Around this central element, we develop concepts, methods and tools to investigate and to quantify the connection between climate, cryosphere (permafrost, glaciers, snow) and geomorphodynamics.

In this thesis project a precision sensing system for detecting ambient vibration patterns [6] as well as slope movement [7, 8, 9] based on a multi-sensor of low-cost sensors suite shall be developed. The sensor platform should be configurable w.r.t. sensor operating modes and extensible w.r.t. on-board signal processing. Low-cost sensors offer a significant cost benefit over precision equipment. Furthermore, classical geotechnical sensing systems do not allow operating based on duty-cycles (schedules) or to control one sensor based on conditions originating from another sensor. In many cases, duty cycling or operation based on an event-trigger has the potential of saving significant on-time resulting in reduced resource usage (power, storage, bandwidth, analysis overhead).

In a previous project, a triggered geophone platform [4, 5] has been developed that allows operating a single low-cost geophone sensor based on an event-trigger and integrates with the eLWB wireless sensor network [4, 14]. We now want to extend the capabilities of such a sensing systems with further sensors targeting at the exploration of more complex operating modes. This thesis explores how to extend the given event-triggered geophone architecture for 3 geophones (3-axis configuration), a GNSS receiver as well as inclinometers. Depending on the actual use case we want to be able to select which sensors are operated in which mode (triggered, scheduled, continuous), at which rate they are sampled and how data is stored or transmitted for analysis purposes. The work builds on prior work by Akos Pasztor [5] and Matthias Meyer [4] and start from this hardware design as well as the geophone system software based on FreeRTOS. The goal of this project is to integrate the sensors including necessary frontends, implement software to operate the sensors and store the data on an SD card memory. An extension to more complex on-board processing is optional.

Master Thesis Project: Detecting Ambient Vibration Patterns using Multiple Sensors

The following sensors shall be considered:

- Low cost 3-axis geophone sensors (ION SM-6 series) with feedback amplification stage (period extension)
- L1/L2 GNSS module with active antenna (u-blox F9P series)
- 2-axis inclinometer (VTI/MURATA SCA830 or similar)
- 6-axis IMU sensor (ST LSM303C or similar)

Challenges that need to be addressed:

- Feedback amplification/bandwidth extension similar to [12, 13] in order to extend the sensing range of low-cost geophones to lower frequencies.
- Sensor operating modes: Triggered, scheduled, continuous configurable per sensor.
- Time synchronization via DPP/eLWB or GNSS/PPS. Requirements tbd.
- Flexible configuration of sensor operating modes, on-board data capture and storage
- Integration with BOLT/LWB for wakeup from the network, dissemination of health/status data and low data rate dissemination of trigger events or local processing results.

Knowledge resources at ETH Zurich:

- DPP/eLWB integration: Reto Da Forno (TIK)
- Geophone filter/amplification/digitizer frontend Domenico Giardini, John Clinton (SED)
- Geophone processing Donat Faeh (SED), Fabian Walter (VAW), Samuel Weber (TIK/TUM)
- GNSS processing: Roland Hohensinn (IGP)
- Geophysical/seismic applications: Samuel Weber (TIK/TUM), Jeff Moore (U Utah), Fabian Walter (VAW)

A successful prototype shall be tested in a lab setting as well as optionally on a PermaSense field site.

Thesis Project Assignment

- Formulate a time schedule and milestones for the project (max. duration 6 months). Discuss and approve this time schedule with your supervisor.
- Familiarize yourself with relevant past works within the project and the significant literature in the field. Search for new approaches and examine which concepts and new components could be of use here. Position your work within this context.
- Develop a specification for the sensing system system. This includes:
    - Definition of the operating modes (triggered, scheduled, continuous) for each sensor type.
    - Evaluation of signal conditioning/amplification stages.
    - Evaluation of the anticipated data volumes, interface and processing requirements.

    - Definition of time synchronization accuracy.
- Implement a hardware design and evaluate a prototype system.
- Characterize the performance of the data acquisition system on a suitable test setup.
- Optional: Integration of local on-board processing (downsampling, compression, local processing, e.g. FFT, RTK, ML-classifier). This can be either targeted by moving to a higher performance STM32f family processor or by making use of a co-processor/host, e.g. an embedded Linux platform.
- Optional: Field testing.
- Document your project with a written report, a short initial presentation, a final presentation and if applicable a demonstration of the prototype. As a guideline, your documentation should be as thorough to allow a follow-up project to build upon your work, understand your design decisions taken as well as recreate the experimental results.

Project Organization

General Requirements

- The project progress shall be regularly monitored using your time schedule and milestones. Unforeseen problems may require adjustments to the planned schedule and milestones. Discuss such issues openly and timely with your supervisor.
- Use the work environment and IT infrastructure provided with care. The general rules of ETH Zurich (BOT) apply. In case of problems, contact your supervisor.
- Discuss your work progress regularly with your supervisor. In excess to such meetings, a short weekly status email to your supervisors is required containing your current progress, problems encountered and next steps.

Handing In

- Hand in two paper copies as well as a single PDF file of your project report including the signed plagiarism statement.
- Clean up your digital data in a clear and documented structure using the SVN repository provided.

References:

[1] https://www.tik.ee.ethz.ch/w1/images/c/ca/Student_Thesis_Guidelines_EN.pdf

[2] https://www.ethz.ch/content/dam/ethz/main/education/rechtliches-abschluesse/leistungskontrollen/declaration-originality.pdf

[4] M. Meyer, T. Farei-Campagna, A. Pasztor, R. Da Forno, T. Gsell, S. Weber, J. Faillettaz, A. Vieli, J. Beutel, and L. Thiele: Event-triggered Natural Hazard Monitoring with Convolutional Neural Networks on the Edge. Proc. Int'l Conf. Information Processing in Sensor Networks (IPSN 2019), April 2019.

[5] Akos Pasztor: Event-Based Geophone Platform with Co-Detection. MSc Thesis. Computer Engineering and Networks Lab, ETH Zurich, 2018.

[6] S. Weber, D. Fäh, J. Beutel, J. Faillettaz, S. Gruber and A. Vieli: Ambient seismic vibrations in steep bedrock permafrost used to infer variations of ice-fill in fractures. Earth and Planetary Science Letters 501, 119-127, November 2018.

[7] F. Walter, M. Wenner, F. Amann: Seismic Analysis of the August 2017 Landslide on Piz Cengalo (Switzerland), EGU General Assembly Conference Abstracts 20, 3163.

[8] LE. Preiswerk, F. Walter: High-Frequency (> 2 Hz) Ambient Seismic Noise on High-Melt Glaciers: Green's Function Estimation and Source Characterization. Journal of Geophysical Research: Earth Surface 123 (8), 1667-1681.

[9] Hohensinn, R.; Geiger, A. Stand-Alone GNSS Sensors as Velocity Seismometers: Real-Time Monitoring and Earthquake Detection. Sensors 2018, 18, 3712.

[10] Felix Sutton, Marco Zimmerling, Reto Da Forno, Roman Lim, Tonio Gsell, Georgia Giannopoulou, Federico Ferrari, Jan Beutel and Lothar Thiele: Bolt: A Stateful Processor Interconnect. Proceedings of the 13th ACM Conference on Embedded Networked Sensor Systems (SenSys 2015), Seoul, South Korea, p. 267-280, November 2015.

[11] J. Havskov, G. Alguacil: Instrumentation in earthquake seismology. Springer, ISBN 978-3-319-21314-9.

[12] G. Vitale, L. Greco, A. D'Alessandro and S. Scudero, "Bandwidth extension of a 4.5 Hz geophone for seismic monitoring purpose," 2018 IEEE International Conference on Environmental Engineering (EE), Milan, 2018, pp. 1-5.

[13] https://www.osop.com.pa/whats-inside-a-lennartz-3d-lite/

[14] Felix Sutton, Reto Da Forno, David Gschwend, Tonio Gsell, Roman Lim, Jan Beutel and Lothar Thiele: The Design of a Responsive and Energy-efficient Event-triggered Wireless Sensing System. Proceedings of the 14th International Conference on Embedded Wireless Systems and Networks (EWSN 2017), Uppsala, Sweden, p. 144-155, February 2017.