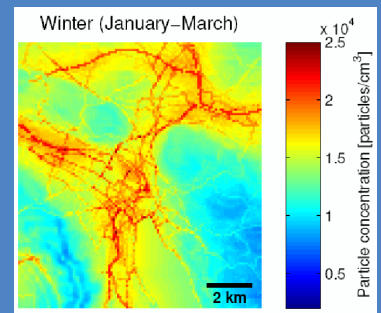




# OpenSense II

CROWDSOURCING HIGH-RESOLUTION AIR QUALITY SENSING

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## What it's about...

*Providing high-resolution air quality maps through the integration of heterogeneous measurement sources in order to understand the health impacts of air pollution exposure.*

## Context and project goals

Novel sensing technologies can provide air quality data with unprecedented temporal and spatial resolution. This opens exciting new opportunities for the study of urban air quality and its impact on health. However, as opposed to traditional, expensive, and highly accurate air quality measurements, the use of dense networks based on low-cost sensors is largely unexploited.

An important issue for obtaining accurate and spatially highly resolved air pollution data is the tradeoff between high cost of accurate air pollution monitoring sensors and the number of such devices required for succinctly monitoring a given geographical area.

Crowdsourcing is a divide-and-conquer technique that has been successfully used for leveraging the intelligence of the crowd (or community) for solving many problems that require community participation (e.g., conducting online polls). Concretely, crowdsourcing can be defined as a participative online activity performed by a group of individuals (or intelligent machines) for mutual benefit between group members or for various other incentives (economic, social recognition, self-esteem, social responsibility), while the crowdsourcer will obtain and utilize the data collected by the user to his/her advantage.

In OpenSense II, we will leverage and improve methods developed in the framework of the Nano-Tera project OpenSense, particularly on: mobile monitoring of air pollution, sensor and communication platforms, calibration methods, sensor data gathering and visualization, statistical modeling, activity recognition, and personalized health recommendations. By adding the dimension of crowdsourcing and human-centric computation we will study possibilities to incentivize users to make available states based on physical measurements, such as location, motion and pollution, through their mobile personal devices or monitoring assets that they can install in their homes or on their cars.

Using a dispersion model we will compute high-resolution air pollution maps for the cities of Zurich and Lausanne. The model results will provide independent and validated information on air pollutant distributions and will thereby greatly help assess the quality of the sensor data and their suitability to measure city-scale air pollution levels. In addition, we will study concrete applications that measure the impact of long- or medium-term exposure to air pollution on human health and evaluate the potential of crowdsourcing for providing feedbacks to users.

## How it differentiates from similar projects in the field

- Combining the information from a dense sensor network with high-resolution dispersion modeling is a new approach for assessing air pollution levels and human exposure in the complex urban environment
- The systematic evaluation of a large variety of low- and medium-cost sensors for air pollution monitoring in on-line and real-world settings is unique and of high value for a wide range of stakeholders
- Involving private citizens as both providers of data and users of health recommendations is a novel contribution and will effectively close the loop between data gathering and the end-user.

## Quick summary of the project status

- Deployment and validation of thirteen sensor nodes in Lausanne.
- Evaluating the performance of low-cost gas sensors based on field experiments.
- Development of a novel algorithm for automatic multi-hop sensor calibration in mobile sensor networks.
- Design and development of a prototype of a flexible sampling system allowing for passive/active and open/closed operation.
- Development of a novel rewarding mechanism, called the Divergence-based Bayesian Truth Serum.
- Development of a novel incentivizing mechanism called SeqTGreedy.
- Development and evaluation of land-use regression models to create pollution maps with a high spatial resolution of 100m x 100m for the city of Zurich. The maps are integrated into a stand-alone application for iOS and Android devices to compute healthy routes for city dwellers.
- Successful setup of the GRAMM/GRAL model system for the cities of Lausanne and Zurich and 10 years of high resolution maps of PM10 and NOx produced for Lausanne.
- Exploration of the association of short-term exposure to PM10 with systolic blood pressure, diastolic blood pressure, and pulse pressure in two Swiss population-based studies.
- Analysis of renal function data (from SKIPOGH and CoLaus studies) and its association with PM10 levels.

## Success stories

### Awards:

Best paper award PerCom 2014 (David Hasenfratz, Olga Saukh, Christoph Walser, Christoph Hueglin, Martin Fierz, and Lothar Thiele, Pushing the Spatio-Temporal Resolution Limit of Urban Air Pollution Maps)

Best paper award IPSN 2015 (Olga Saukh, David Hasenfratz, and Lothar Thiele, Reducing Multi-Hop Calibration Errors in Mobile Sensor Network)

### Presence in the media:

There was a large media coverage about the generated high-resolution pollution maps for Zurich:

- Newspapers and radio: NZZ, Tagesanzeiger, Blick, 20Minuten, radio stations, ETH News (Jan. 2014)
- Television: Tele TOP (broadcast in the region of Zurich and Northeast Switzerland, Jan. 2014)

- BAFU Magazin Umwelt 2/2014 (May 2014)

An article on the project was included in the June-July 2014 issue of the internal journal of the TL (Transports publics de la région lausannoise).

## Main publications

David Hasenfratz, Olga Saukh, Christoph Walser, Christoph Hueglin, Martin Fierz, and Lothar Thiele, Pushing the Spatio-Temporal Resolution Limit of Urban Air Pollution Maps, Proceedings of the 12th International Conference on Pervasive Computing and Communications (PerCom 2014).

Y. Kim, J. Eberle, R. Hanninen, E. C. Un and K. Aberer., Mobile observatory: an exploratory study of mobile air quality monitoring application, ACM conference on Pervasive and ubiquitous computing - UbiComp '13.

R. Gwadera, M. Riahi and K. Aberer., Pattern-wise trust assessment of sensor data., 15th IEEE International Conference on Mobile Data Management.

B. Agir, T. G. Papaioannou, R. Narendula, K. Aberer and J.-P. Hubaux., User-side adaptive protection of location privacy in participatory sensing, Geoinformatica, vol. 18, num. 1.

Adish Singla, Andreas Krause, Incentives for Privacy Tradeoff in Community Sensing, AAAI Conference on Human Computation and Crowdsourcing (HCOMP), 2013.

Adish Singla, Ilija Bogunovic, Gábor Bartók, Amin Karbasi, Andreas Krause, Near-Optimally Teaching the Crowd to Classify, Proc. International Conference on Machine Learning (ICML), 2014.

Gagan Goel, Afshin Nikzad, Adish Singla, Mechanism Design for Crowdsourcing Markets with Heterogeneous Tasks, AAAI Conference on Human Computation and Crowdsourcing (HCOMP), 2014.

G. Radanovic and B. Faltings, Incentives for Truthful Information Elicitation of Continuous Signals, Proceedings of the 28th AAAI Conference on Artificial Intelligence (AAAI'14).

D.-H. Tsai, I. Guessous, M. Riedkier, F. Paccaud, J.-M. Gaspoz, J.-M. Theler, G. Waeber, P. Vollenweider, M. Bochud, Short-term Effects of Particulate Matters on Blood Pressure in the Swiss Population-based Bus Sante and Colaus Studies, Journal of Hypertension, 2014.

D. Hasenfratz, O. Saukh, C. Walser, C. Hueglin, M. Fierz, T. Arn, J. Beutel, and L. Thiele, Deriving High-Resolution Urban Air Pollution Maps Using Mobile Sensor Nodes, Pervasive and Mobile Computing Journal.

Julien Eberle, Tri Kurniawan Wijaya, and Karl Aberer, Online Unsupervised State Recognition in Sensor Data, IEEE International Conference on Pervasive Computing and Communications (PerCom 2015).

Berker Agir, Jean-Paul Calbimonte and Karl Aberer, Semantic and Sensitivity Aware Location-Privacy Protection for the Internet of Things, Workshop on Society, Privacy and the Semantic Web - Policy and Technology (PrivOn 2014).

Adish Singla, Marco Santoni, Gabor Bartok, Pratik Mukerji, Moritz Meenen, Andreas Krause, Incentivizing Users for Balancing Bike Sharing Systems, Proceedings of the 29th AAAI Conference on Artificial Intelligence (AAAI'15).

Radanovic, G. and Faltings, B. , Incentive Schemes for Participatory Sensing, Proceedings of the 14th International Conference on Autonomous Agents and Multiagent Systems.

Radanovic, G. and Faltings, B. , Incentives for Subjective Evaluations with Private Beliefs, Proceedings of the 29th AAAI Conference on Artificial Intelligence (AAAI'15).

O. Saukh, D. Hasenfratz, L. Thiele, Reducing Multi-Hop Calibration Errors in Mobile Sensor Network, International Conference on Information Processing in Sensor Networks, IPSN'15.

A. Marjovi, A. Arfire, A. Martinoli, High Resolution Air Pollution Maps in Urban Environments Using Mobile Sensor Networks, International Conference on Distributed Computing in Sensor Systems (DCOSS 2015).

Mueller, M. D., M. Wagner, I. Barmpadimos, and C. Hueglin, Two-week NO2 maps for the City of Zurich, Switzerland, derived by statistical modelling utilizing data from a routine passive diffusion sampler network, Atmospheric Environment.