Automatic Monitoring System

Samuel Weber, ETH Zurich
Our patient does not fit into a laboratory
So the laboratory has to go on the mountain.
PermaSense System Architecture

- Wireless systems, low-latency data transmission
- Customized sensors
- Ruggedized equipment
- Data management
- Planning, installation and operation of large deployments
Automatic Monitoring System, SloMove 2013, SLF Davos
Sensor Nodes

- Optimized for ultra-low duty cycles (0.167%)
- Static, low-rate sensing (120 sec)
- Generic interface for analog and digital sensors
- 4 years of independent operation (~200 μA avg. power)
- < 0.1 MB/node/day
- Ruggedized for alpine extremes
Wireless Sensor Network

- Wireless Sensor Network Technology allows to acquire mountain phenomena
- Dozer - ultra low-power data gathering system
- Self organizing multi-hop network
- Optimized for ultra-low duty cycles
- 5+ years experience, ~560’000’000 data points, 165.9 GB

Advantages
- Enables spatially distributed field measurements
- Data all year-round at near real-time
- No long cables, less problems with lightning
- Low maintenance

Challenges
- Harsh environment
- Low power consumption
- Time synchronization
Field Site Support

- Base station (Linux)
  - Local data buffer, aggregation
  - Redundant connectivity
  - Global time synchronization
  - Database synchronization

- Solar power system

- WLAN backbone

- Meteostation and webcams
WLAN Long-haul Communication

- WLAN (802.11a) backbone using directional links
- Leased fiber/DSL from Zermatt Bergbahnen AG to mountaintop
- Commercial components (Mikrotik)
- Weatherproofed, protected
• Global Sensor Network (GSN)
  – Data streaming framework from EPFL (K. Aberer)
  – Organized in “virtual sensors”, i.e. data types/semantics
  – Hierarchies and concatenation of virtual sensors enable on-line processing
  – Dual architecture translates data from machine representation to SI values, adds metadata

• Infrastructure monitoring
  – Monitoring of all critical infrastructure using Zabbix, Cacti and Smokeping
  – Alerting system using email and SMS
GSN Web User Interface Demo

http://data.permasense.ch
GSN – Network Topology – Health
GSN – Network Topology – Position Map
Vizzly: Visualization of Large Data

- Fast access to millions of data samples
- Pan, zoom, channel selection
- Combination of historic and real-time data

[Keller IPSN 2011, SenseApp 2012]
GSN – IP Network
Current Deployments 3500 m a.s.l.
X-Sense Project
X-Sense Hypothesis

Anticipation of future environmental states and risk benefits from
- environmental sensing at diverse modalities and scales,
- process modeling

Research Focus
- Active & inactive rock glaciers
- Debris flow, open fractures, slope failures
X-Sense System Architecture

Data processing, fusion, storage

IN-SAR Satellite Imaging

Reference GPS
High Resolution Imaging

Non-moving position

Moving debris moving rock slope

Wireless Sensors
Crack Dilatation
Temperature

GPS Sensor

Base Station
Solar Power
X-Sense Field Site *Matter Valley*

**Installed sensors:**
- 25 L1 GPS sensors
- 3 Meteo stations
- 3 Cameras
- 2 High-resolution cameras
- 1 High-resolution camera robot

Installation started August 2010, full operability from August 2011
Selected Environmental Science Results
GPS Measurement Devices

Low-cost L1 GPS Devices

- Dual strategy: Logging units & wireless sensors
- Differential processing yields mm-cm accuracy for daily positions
- Very high duty cycle required (10-100%)
- Tilt compensation with inclinometers

[Wirz, WLF 2011, Buchli SGM 2011]
Example GPS Data Analysis

- Post-processing of GPS time series
  - Correction to coordinates at ground level
  - Derivation of differing measures of velocity
Changing Opportunities with X-Sense

• X-Sense delivers data at unprecedented levels of detail
  – Spatial scale – 25 GPS stations
  – Temporal scale – 30 sec intervals
  – High accuracy – cm to mm scale

Mean annual velocity
- 0.1 m/year
- 2 m/year

[Wirz et al., in prep.]
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[Wirz et al., in prep.]
Rock/ice Temperature

Aim: Understand temperatures in heterogeneous rock and ice

• Measurements at several depths
• Two-minute interval, autonomous for several years
• Survive, buffer and flush periods without connectivity

[Hasler 2011]
Thermal Offset at Matterhorn/Jungfraujoch

Matterhorn: Crack Dilatation

Aim: To understand temperature/ice-conditioned rock kinematics

- Temperature-compensated, commercial instrument
- Measurement of multiple axes
- Reduction of cabling to a minimum
- Protection against snow-load and rock fall
Results: Rock Kinematics

PermaSense

- Consortium of several projects, start in 2006
- Multiple disciplines (geo-science, engineering)
- Fundamental as well as applied research
- More than 20 people, 9 PhD students