SenseWeb: Wikipedia of Sensors

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1. Share *data*
   - Swivel, Sloan sky survey, Fluxdata.org, BWC Data Server

2. Deploy macro-scopes
   - Addresses few domains

3. Share all *instrumentation*: SenseWeb
SenseWeb Example

Scientists in Alaska (NASA, NOAA, UAS)
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Scientists in Swiss Alps (EPFL, ETH, WSL, NF)
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Swiss Snow and Avalanche Info (SLF)
System Design
SenseWeb: System Design
SenseWeb: Front-end

- In situ data analysis
- Discover correlations, dependencies, and distributions
  - Comparison chart, Contour maps, temporal exploration

http://atom.research.microsoft.com/sensormap/
Design Challenges

Heterogeneity
- Capability: bandwidth, power, computation
- Willingness to share
- Measurement accuracy

Scalability
- Streaming all raw data from all sensors to all applications not feasible

Security and Privacy

Data Verifiability, Trust
Minimize Sensor Probes

- Consider value of probing sensors
  - **Information value** (collapse uncertainty)
  - **Demand** (usage: “utilitarian” impact)
- Sensor availability
  - **Predict** based on history
- Preferences
  - **Abide by preferences** (Eg. Privacy)

Streaming Multiple Sensors to Multiple Applications

- Detect overlap
  - In sensors used
  - In computation performed on streams
    - Including intermediate steps

Details:
Mobile Contributors in SenseWeb

+ More coverage
- Hard for application to track relevant devices

• **Solution**: data centric abstraction
  – Location based indexing
    • using GPS, cell-tower triangulation, content based location
Using Data Centric Abstraction

Tests run on real world dataset (Bellevue street traffic).

N/Z: number of sensors per zone
Note: For similar coverage, the number of sensors needed is much less with data centric abstraction

Details:
Other Technical Challenges

• Enhance visualization performance in SensorMap
  – Details: ACM GIS 2008

• Tasking sensors efficiently
  – Share probing load by sensor quality, resource availability, and application tolerance (in submission)

• Preserve query response accuracy
  – Ensure gateway has included all sensors available in its calculation
SenseWeb: Collaborative R&D
Collaborative Engagements

- 11 universities funded through Microsoft External Research Request for Proposals
- Additional universities and scientific/government agencies involved through SenseWeb usage
Nanyang Technological University: NWS

• National Weather Study: mini weather stations in schools throughout Singapore
Harvard: CitySense

• Large scale urban monitoring
• Network health sensing
• Urban environment sensing
U. Melbourne: Great Barrier Reef

- coral reef ecosystems: early indicators of climate change and human influence
Debris flow sensing

• 921 earthquake in 1999 caused land collapse
• Crevices formed in rocks and soil: typhoons and surface runoff causes debris flows
• Debris flows cause severe damage to the land, property, and life.
Ohio State U: Kansei

- Sense mobility in urban campus-area habitats
- Sense health/availability of equipment in a test bed
UIUC: ActionWeb

- Monitor mobile activities
- First person activities (Eg. Patient lifestyle change)
U Virginia: MetroNet

- Sensors at storefront windows in Charlottesville
- Count people passing store/enter store
  - Analyze effects of advertising, window displays, weather, events on pedestrian business
U Washington: Indoor Events

- Define sophisticated high-level events over the low-level sensor data
- Gracefully handle input data errors
- Uses RFID sensors
Urban air pollution monitored using car mounted mobile sensors
Advantages to Users

- Re-use spatio-temporal visualization and analysis tools
- Data sharing
- Get mapping UI, VE imagery, terrain data
- Get indexing, database features
- Get more similar and related sensors
- Ease of management of sensors

Advantage to Researchers

- Understand app needs: data analysis, visualization
- Prototype applications: environmental, urban, scientific
- New types of sensors: vector sensors
- New capabilities: mobility, semantic web, wiki access
- Work without own deployment
- Get access to variety of hardware

SenseWeb Collaboration Experience
Tools for Sensor Sharing

http://research.microsoft.com/nec/senseweb

• Internet gateway for sensors
  – Open web service API
    • Supports several sensor types via semantic hierarchy
• Tools available for download
  – Tutorials available online
Action Items

• Seed Applications
  – Immediate use to prompt rapid deployment

• Community involvement
  – Tools and platforms to ease sharing

PEOPLE/PRIVATE
Flooded road image from cell-phones

GOVT.
Govt. deployed stream sensors

SCIENTISTS
Scientist deployed soil moisture sensor
Thank You
# Applications of Shared SN’s

## Community Fitness and Recreation

- Runners: Where are sidewalks broken? Construction finished on 24th St?
- Mountain Bikers: Average biker heart rate at Adams Pass on trail 320? [SlamXR]
- Surfer: What is the wave level and wind speed at Venice Beach now?

## Real Time Information

- Public initiated instant news coverage

## Science

- Continent scale phenomenon study using sensors deployed by multiple labs

## Business

- What are people doing tonight? Restaurant waiting times in midtown?
- Mall visitor activity and parking usage across franchise outlets worldwide
Example: Rainstorm Management

**SENSOR CONTRIBUTORS**

- Govt. deployed stream sensors (Eg. USGS)
- Geo-stamped flooded road image from cellphones (Eg. SensorPlanet)
- Scientist deployed soil moisture sensor network (Eg. LifeUnderYourFeet)
- Data from home weather stations (Eg. Wunderground)

**SENSING APPLICATIONS**

- Road flooding aware cab dispatch
- City road route management and repairs
- Tourist day planner
- Landscape maintenance scheduling and inventory
- Mountain bike router
SensorMap Usage

**Experiment Planning**
To view sensor layout and visualize measurements in real-time to decide the placement of sensors

**Deployment Monitoring**
To inspect real-time output of sensors, and to discover and fix broken sensors

**Data Analysis**
To visualize dependencies among different measurements and correlations with topological terrains

- Large deviations! Concentrate more stations here.
- Temperature Vs terrain?
- Temperature Vs humidity?
Tasking Heterogeneous Sensors

- Select uniformly rather than overloading the best sensors
- Leverage lower capability sensors when usable for a query
- Learn and adapt to sensor characteristics: availability, bandwidth
- Weighted reservoir sampling
  - Weighted random selection, with desired number of sensors

Sensors
- Involvement in different apps

SenseWeb Sensor Selection

Applications
- Tolerance in task execution
Accept sensor registration

Accept query and sensor list from COLR-tree

Learn sensor availability and initialize characterization metric

Assign involvement based weights for given query application group

Assign query tolerance based weights

Select $r_i$ sensors from list using reservoir sampling, access data

Satisfactory response?

Select additional sensors and access data

Return sampled data

Update sensor characterization metrics
Tasking Algorithm Performance

- Test on USGS stream water sensors
  - Random selection vs. Weighted reservoir sampling