SensorWeb And Its Extension to Support Mobile Sensing

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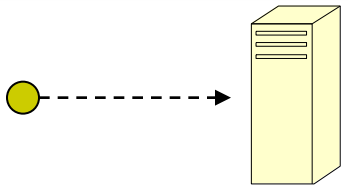
Sensors Everywhere

- Camera(s)
- Microphone(s)
- GPS
- Accelerometer
- Compass
- Gyroscope
- Temperature
- Wireless radio
- …

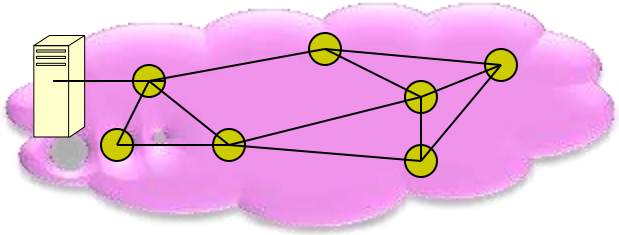
Many sensing applications

Sensing Trends

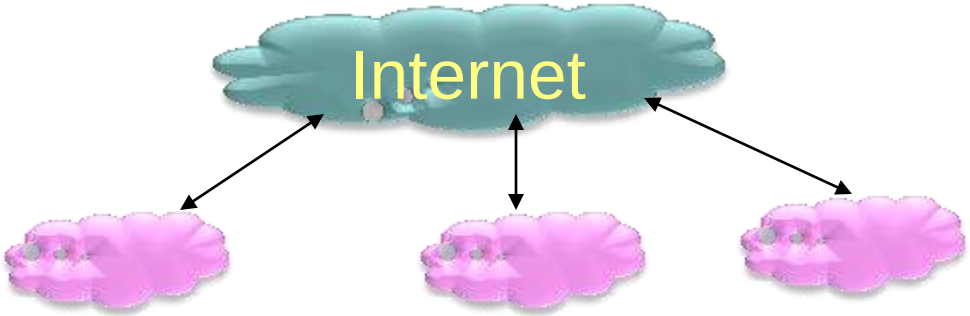
- Generation 1: Remote sensing
  - Collect data to a central server



- Generation 2: In-situ sensing + processing
  - Transmit processed information only



- Generation 3: World-wide Sensor Web



Example: Swiss Experiments

Many isolated sensor deployments

Put all data together for better understanding
Share with other scientists

Temperature
Humidity

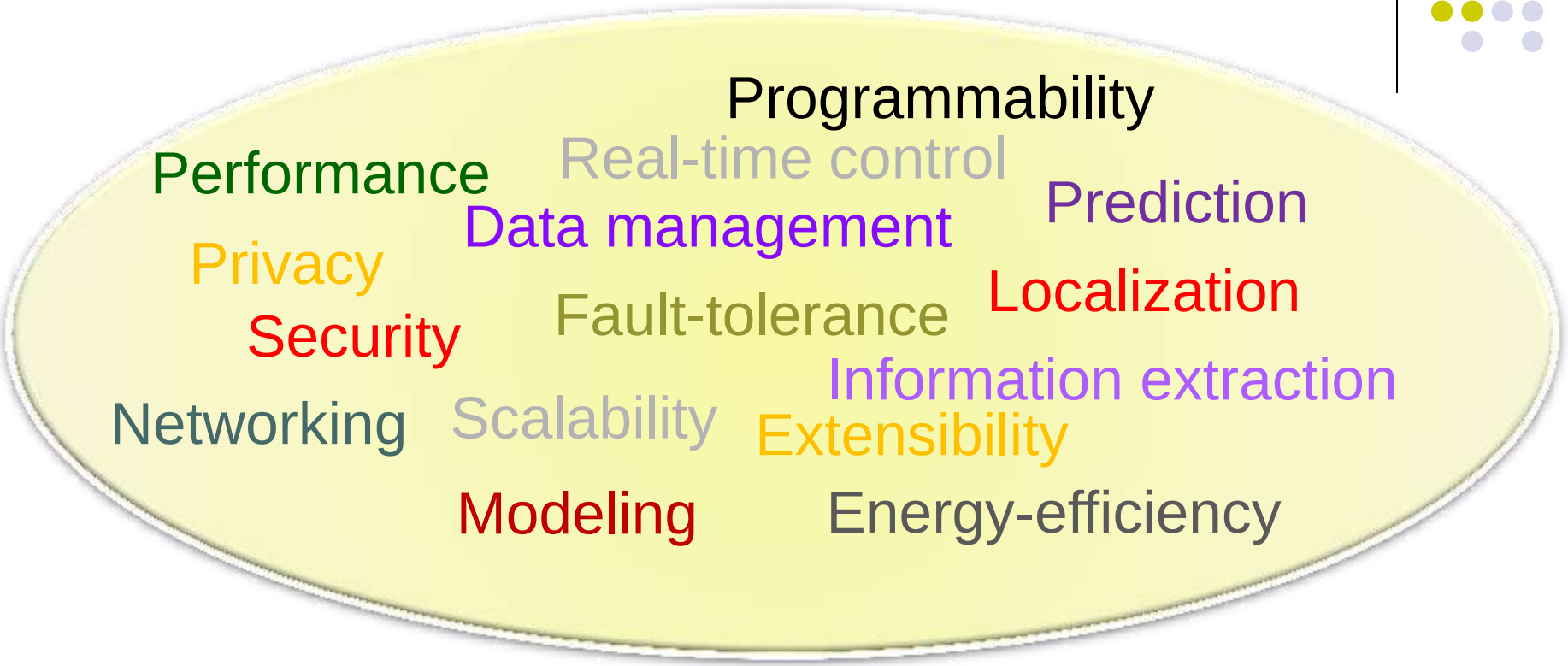
Snow

Soil

Streams

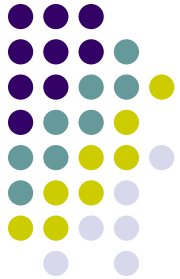
Similar deployments: USGS, NASA, SeaMonster (Alaska), DOT, Community sensors

Cyber-physical System Challenges



We built a **vertical system** to address challenges faced by **environmental scientists**

SenseWeb: Wikipedia of Sensors



- **SenseWeb**: Bring live data to the Web
  - Overlay live data on an interactive map, SensorMap
- Unique set of features
  - Peer production: Anyone can publish his sensors
    - Larger spatio-temporal coverage
    - Amortized cost
  - Extensible: new sensor types and data processing
  - Geospatial data exploration: Search sensors, aggregate and visualize data over interactive map

SensorMap

http://msra.cn/sensormap/

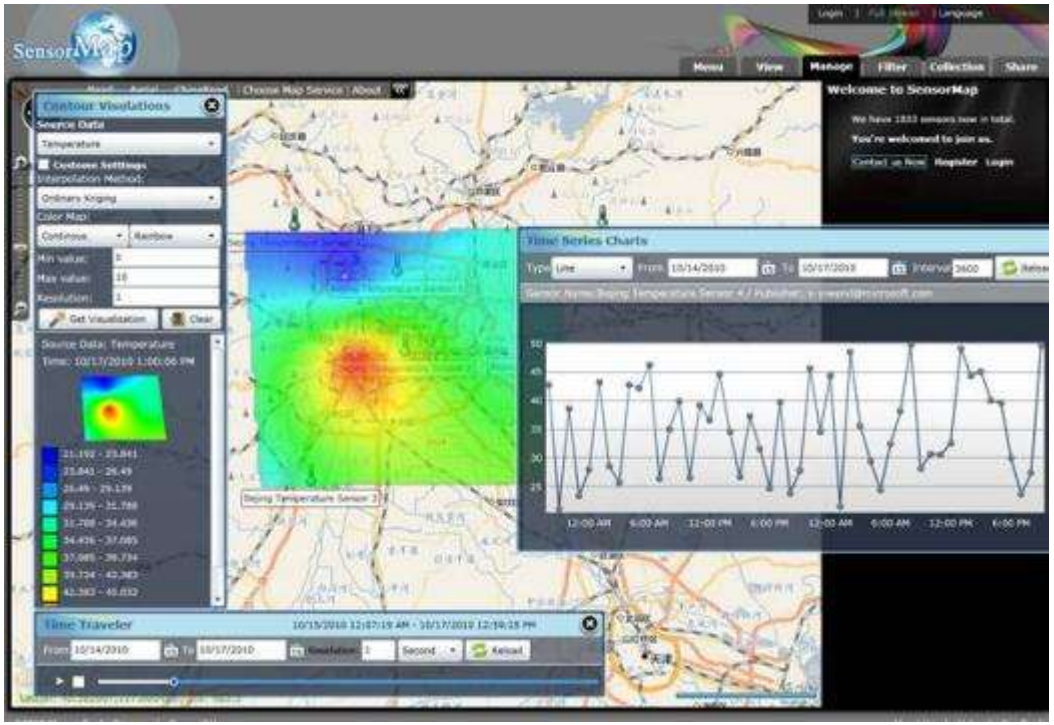
Sensors as Icons
Show real-time data

Search sensors based on geography, type, keywords

Aggregate live data at different zoom levels

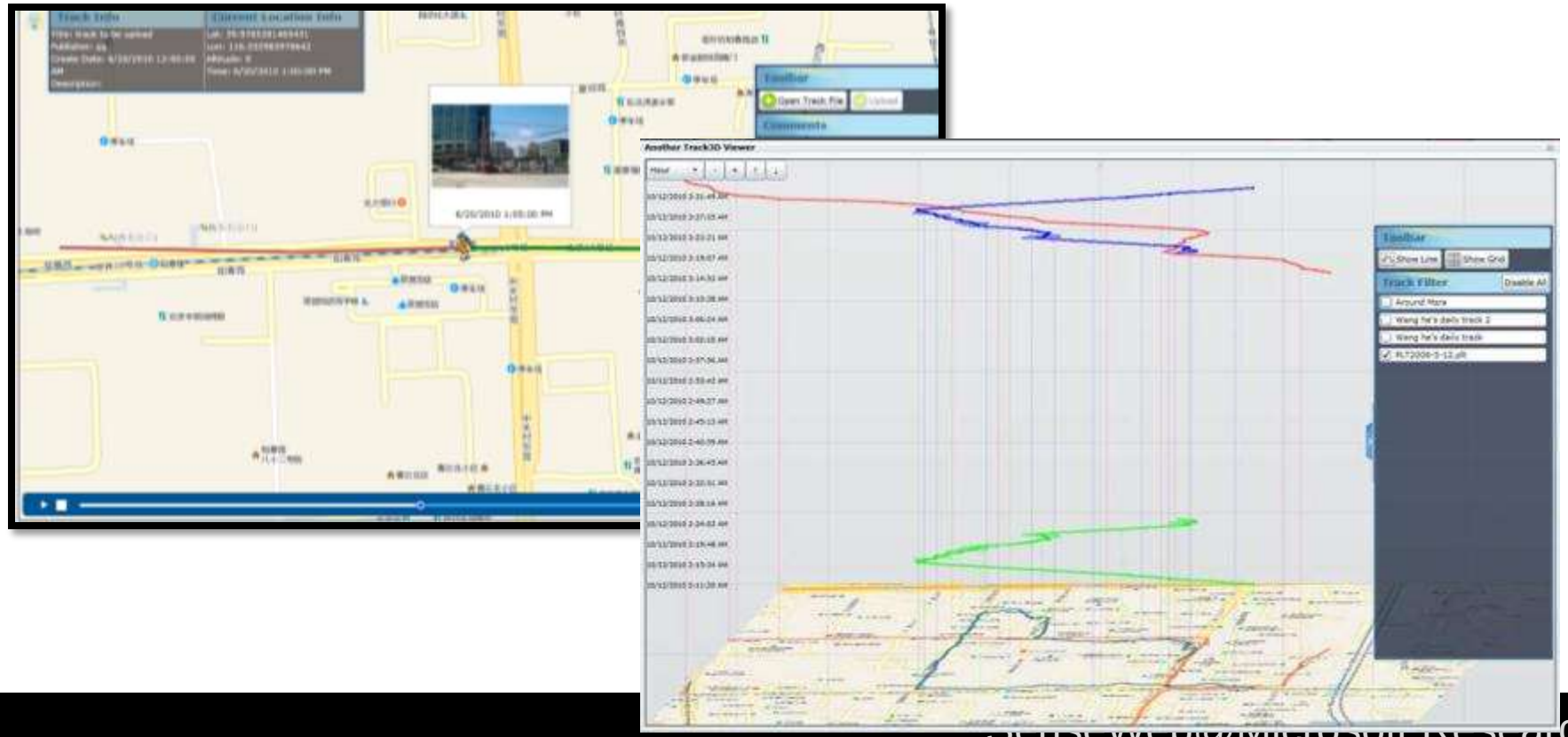
SensorMap

- Visualize sensor data over space and time
  - Charts
  - Time traveller
  - Overlaid contour maps

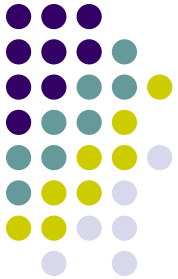


SensorMap

- Support mobile sensing:
  - Tracks (sensory data, and motion states)
  - Spatio-temporal visualization of tracks

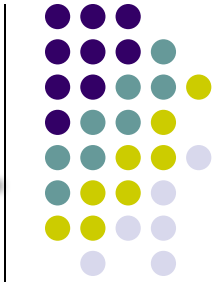


Outline



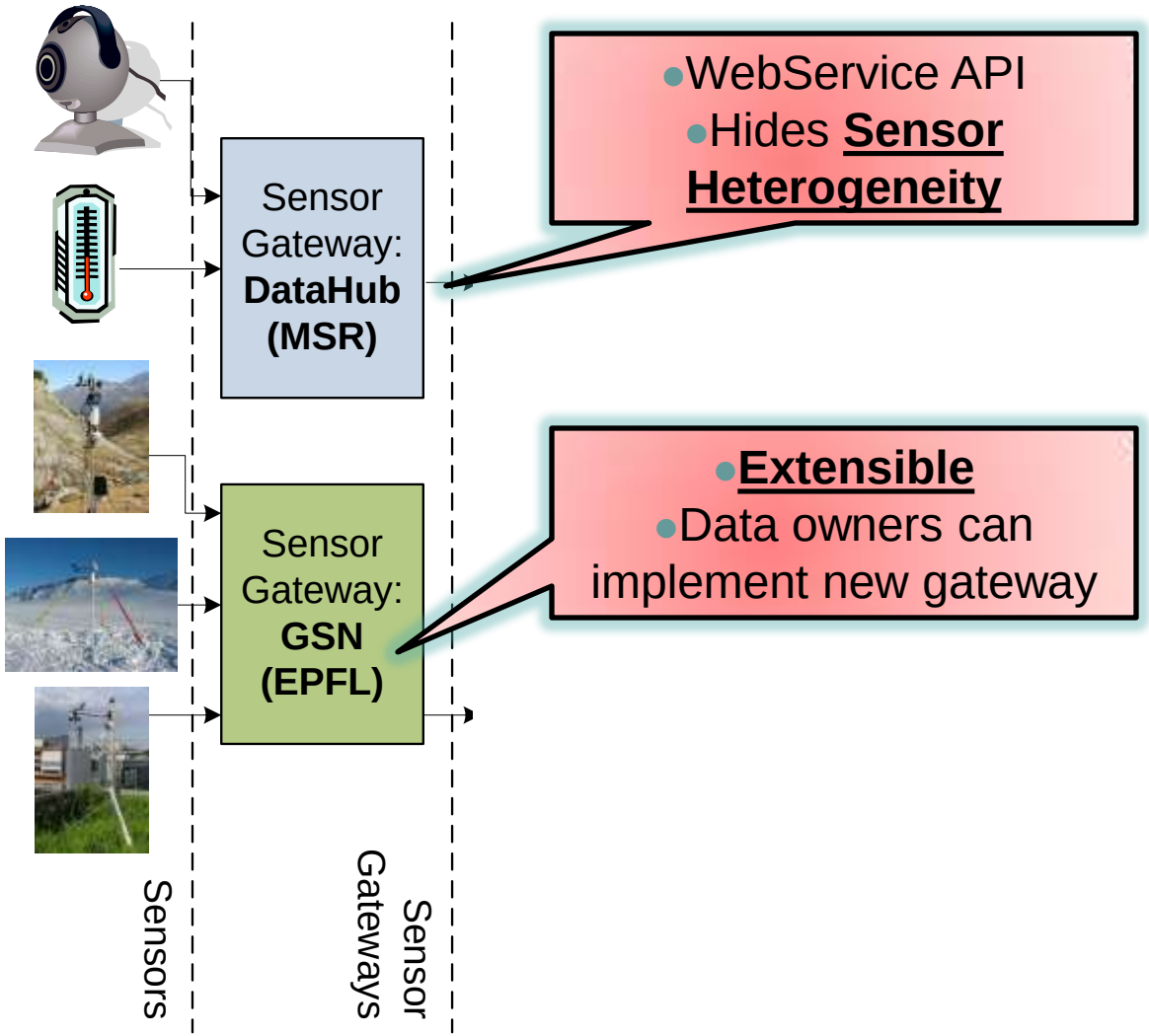
- Context
- SenseWeb Architecture
- Data publishing
- Extensibility
- Scalability
- Mobile sensing support
- Conclusion

Design Challenges

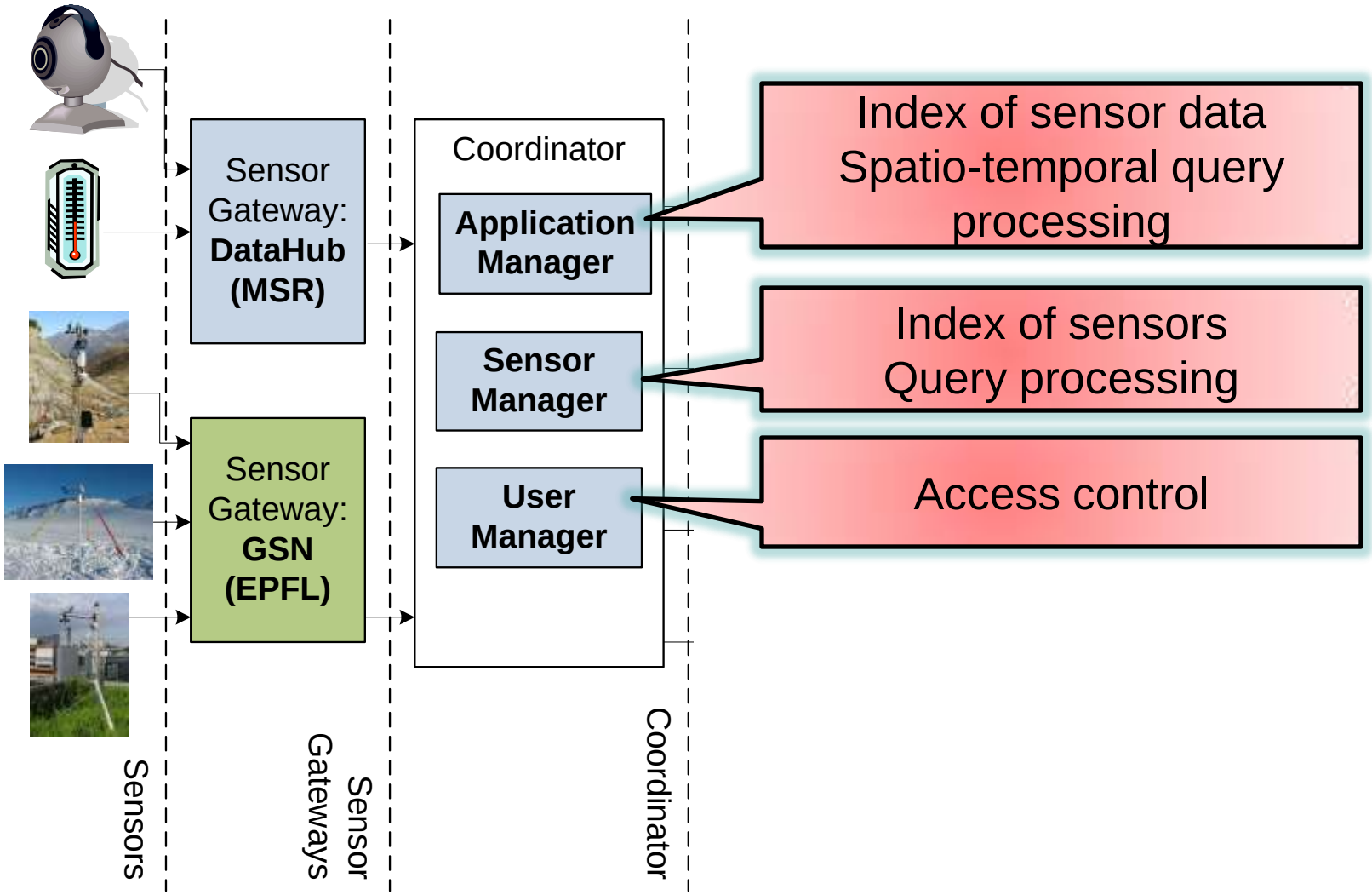


- Data publishing
  - Must make the tasks of acquisition, cleaning, publishing, naming, etc. simple
- Extensibility
  - Must support new sensor types, new data types, new processing, new visualization, …
- Scalability
  - Must support a large number of sensors
  - Must support expensive processing tasks interactively

SenseWeb Architecture



SenseWeb Architecture



SenseWeb Architecture

Sensor Gateway: **DataHub (MSR)**

Sensor Gateway: **GSN (EPFL)**

Coordinator

- **Application Manager**
- **Sensor Manager**
- **User Manager**

Transformer: **Iconizer**

Transformer: **Graph Generator**

Transformer: **Map Generator**

Transformer X

Transformer Y

Generates visualization

WebService API

Extensible

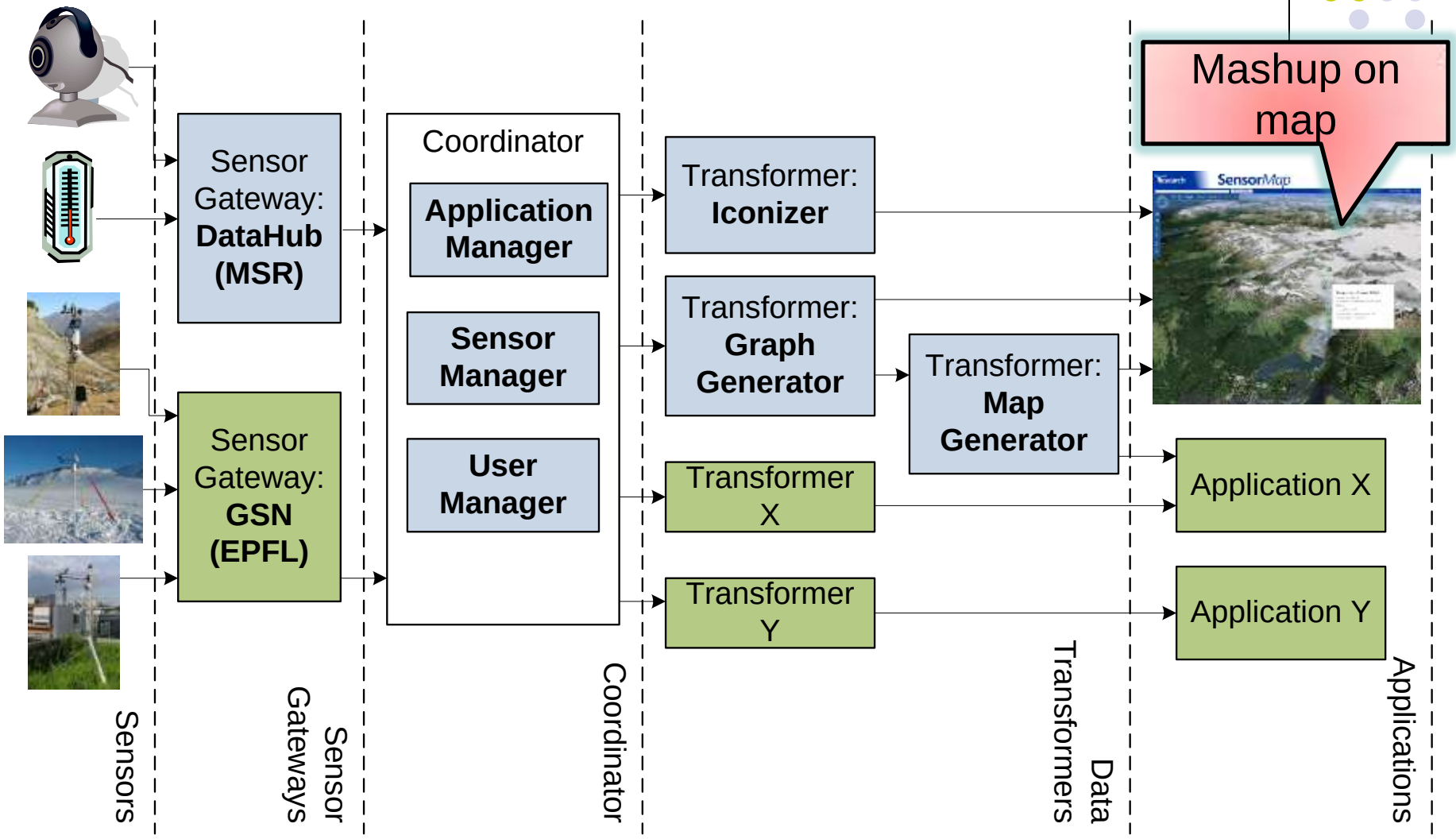
Sensors

Sensor Gateways

Coordinator

Data Transformers

SenseWeb Architecture



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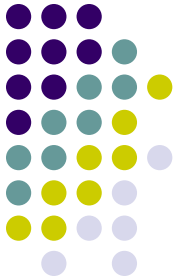

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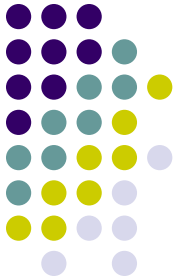
MSRSense: Data Publishing Toolkit



- Programming abstraction
  - Service oriented programming at gateway

- Automate using standards
- Syntax: markup language
- Semantics: ontology
- Interface: web service

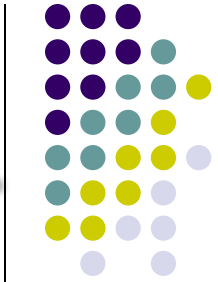
Sensors

MSRSense
Sensor Data Publishing Toolkit

SenseWeb

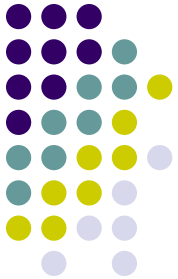
Office Tools

Data Publishing



- Register sensor with metadata
  - Identity: Publisher, sensor name, desc, etc
  - Physicality: Location, report period, etc
  - Connectivity: URL: External or DataHub URL
  - Semantics:
    - Sensor type: thermometer, camera, etc.
    - Data format: HTML, Scalar number, XML, Multimedia (image, audio, video, etc.)
    - Unit

Outline



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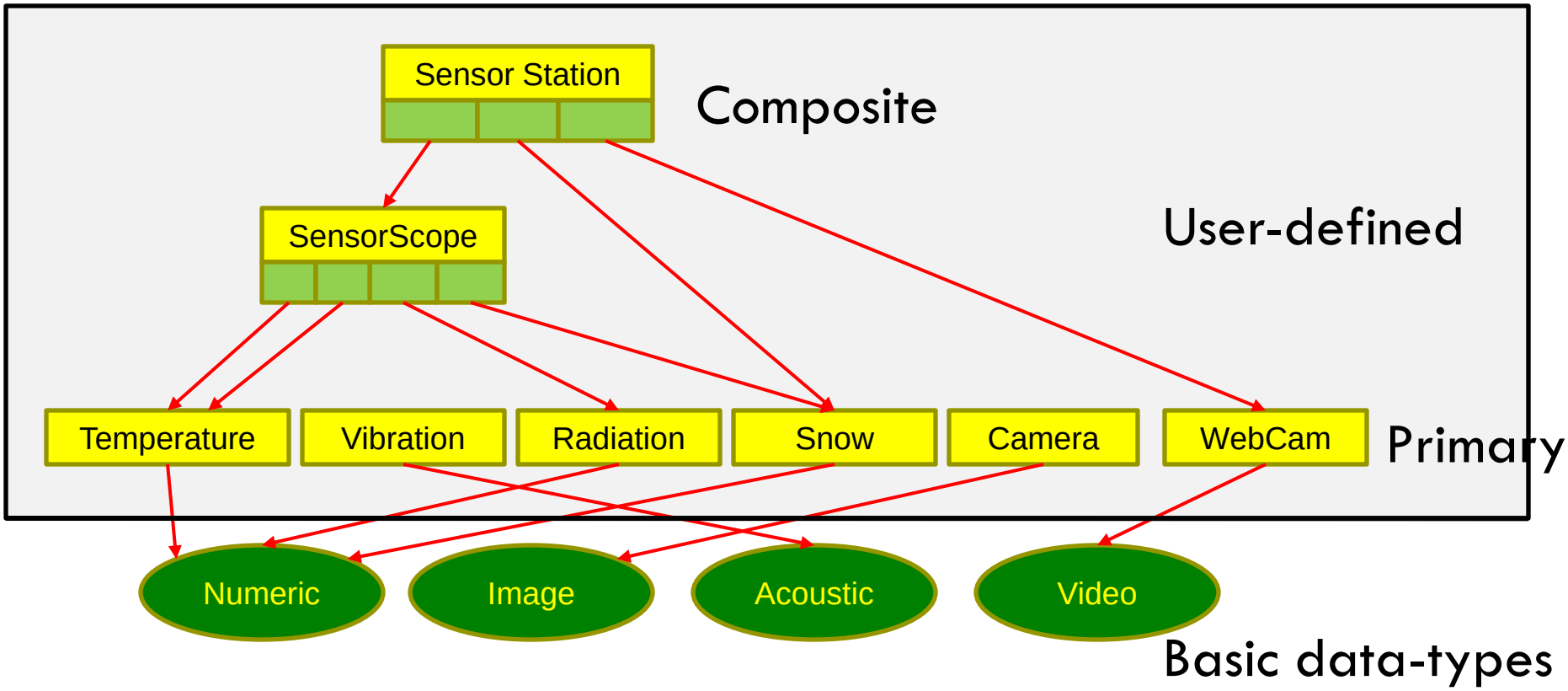
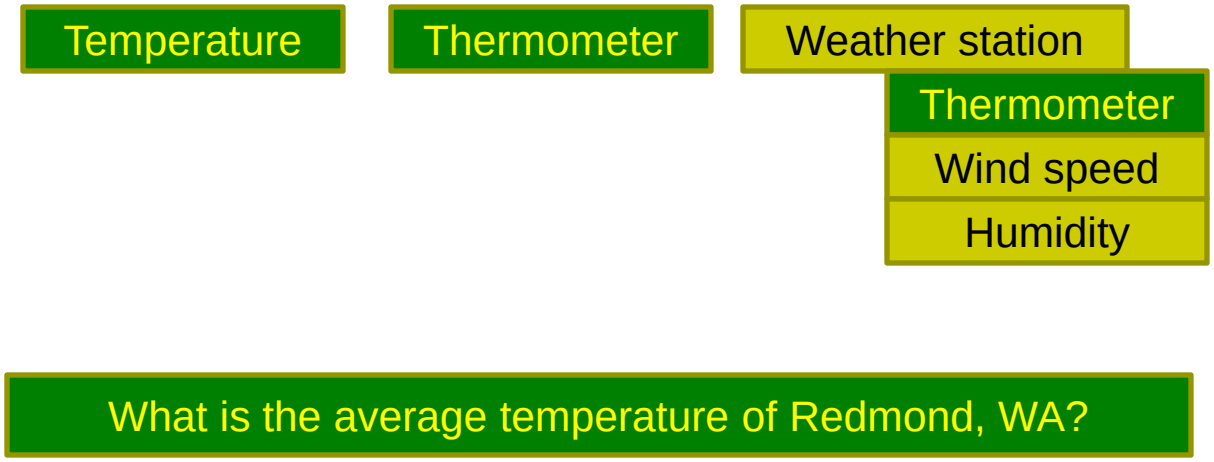
Supporting new sensor types

- Sensor types are used for query processing and visualization
- Basic Idea: Let user compose new types on basic data types



Handling divergence

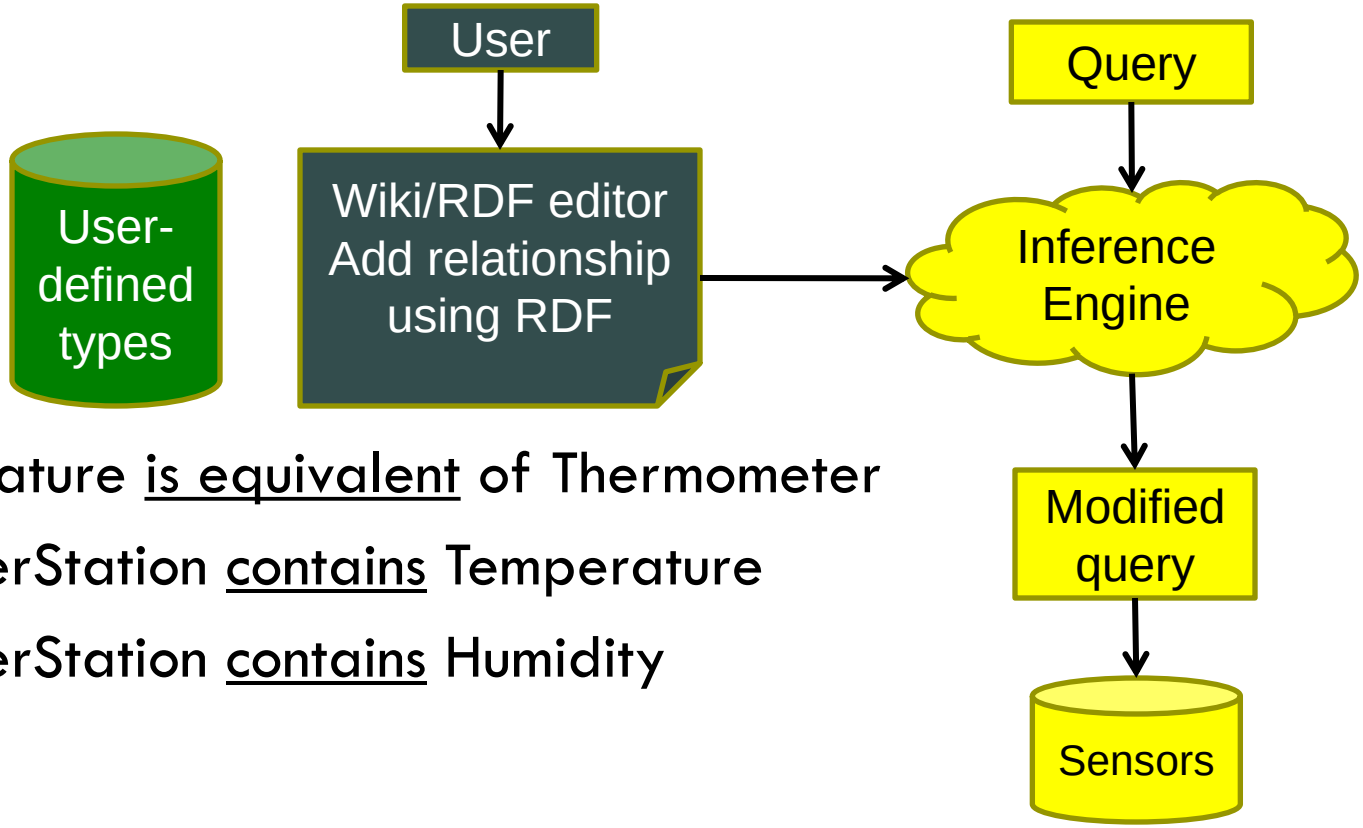
- Challenge: redundant user-defined types



- Solution: Use semantic relationship among types

Type Semantics

- Use ideas from Semantic Web

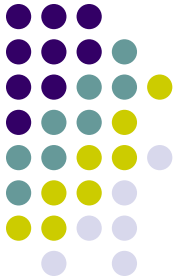


Temperature is equivalent of Thermometer

WeatherStation contains Temperature

WeatherStation contains Humidity

Outline



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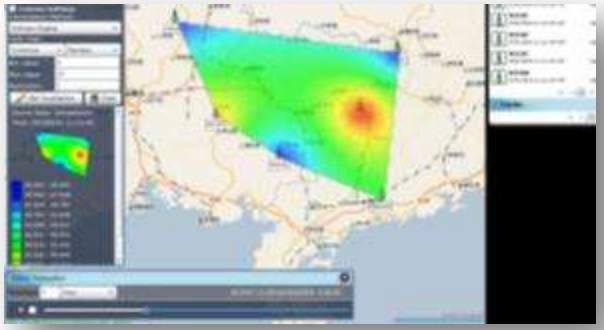
Scalability



Query

Image

Visualization
(Contour Map)

Query

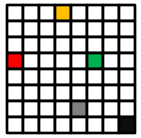
Data

SenseWeb

Sensor
Probe

Data

Sensors



Visualization

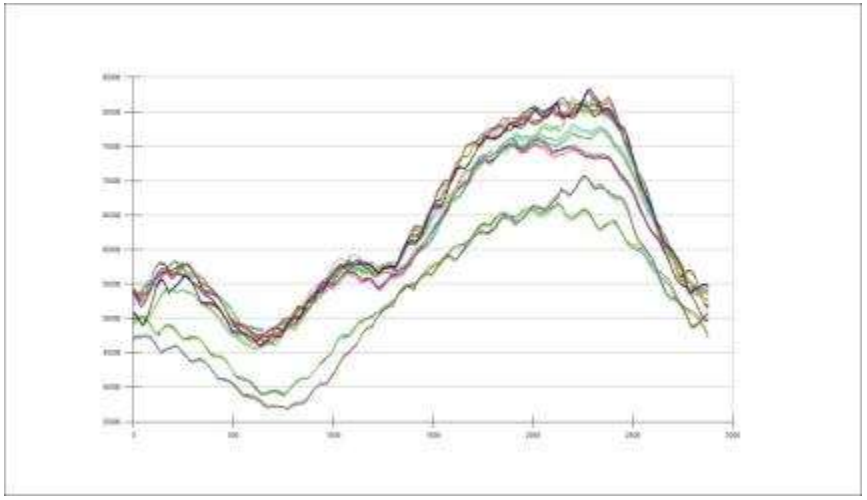
Data mining

Query processing

Storage

Storage scalability

- Compress sensor data

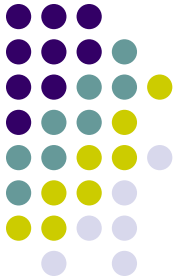


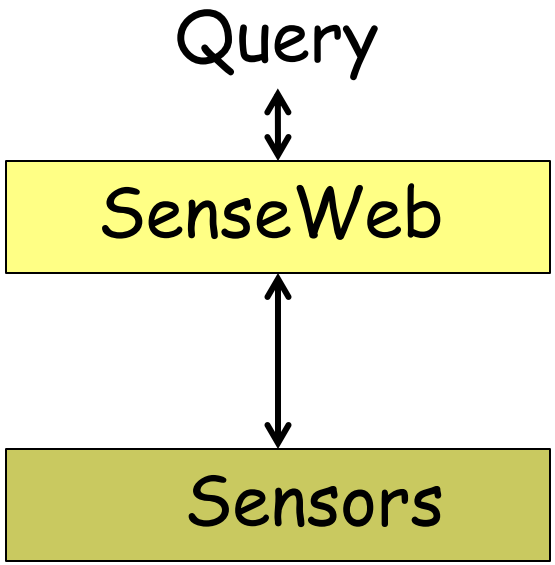
Group similar streams and compress together

- Answer queries on compressed data

Data mining queries in frequency domains

Scalable Query Processing





Data acquisition expensive
Sensors disconnected

Solution: Sample and Cache

Challenges:

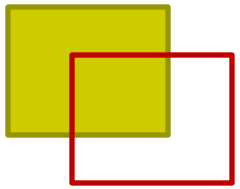
- Unbiased sampling
- Caching aggregates

COLR-Tree

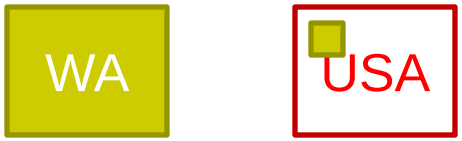
Scalable Visualization

- Contour maps are expensive

- Solution: Cache and reuse contour matrices
- Challenge 1: queries partially overlap
  - Crop cached matrices and combine them



- Challenge 2: queries have different zoom levels
  - Normalize zoom levels



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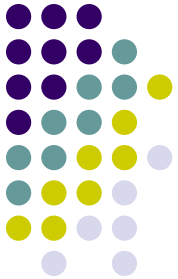

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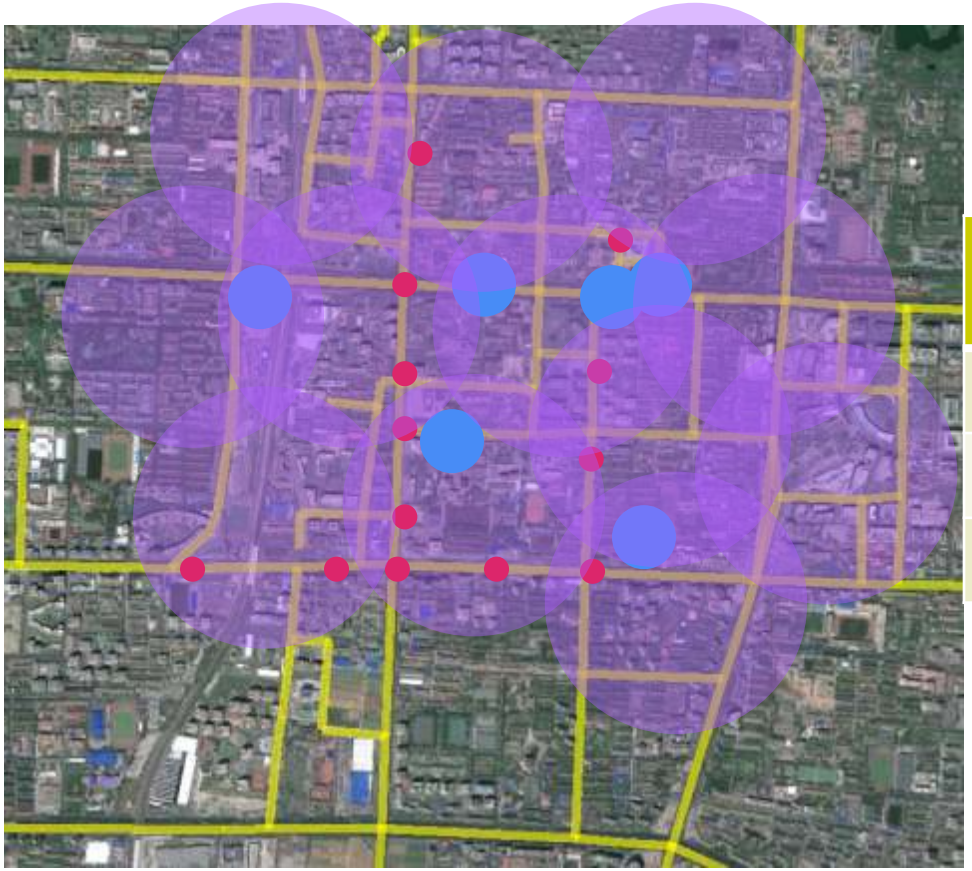
Continuous localization (1)

- Key challenge: energy, energy!
- Localization means, and characteristics

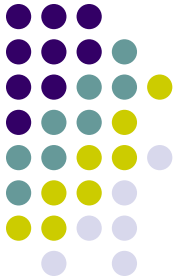


Localization means	Accuracy	Coverage	Battery Lifetime
GPS	~10m	Full, outdoor	2-4hours
WiFi	~30m	Spotted	4-5hours
Cellular	~150m	Full	4hrs/Free

Continuous localization (2)

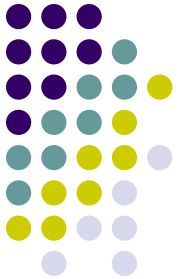
- Solution idea:
  - Resolve the track first, perform point location via interpolation
  - Leverage cheap or free resources:
    - Free radio info: CellID (public WS API)
    - Cheaper sensors: accelerometer, compass (motion and direction)
    - Road map

Data Privacy



- Protect privacy of data from people
  - E.g., Location, health-info, driving habit, etc.
- Solutions: let user publish
  - Noisy data
  - Encrypted data
  - Irreversible features
- Guarantee: cannot infer anything about an individual, but answer aggregate queries
  - Average speed at 520 bridge on Monday morning
  - Correlation of weight increase with medicine intake

Outline



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Application Scenarios

Marc, a hydrologist, utilizes SensorMap during

Experiment Planning

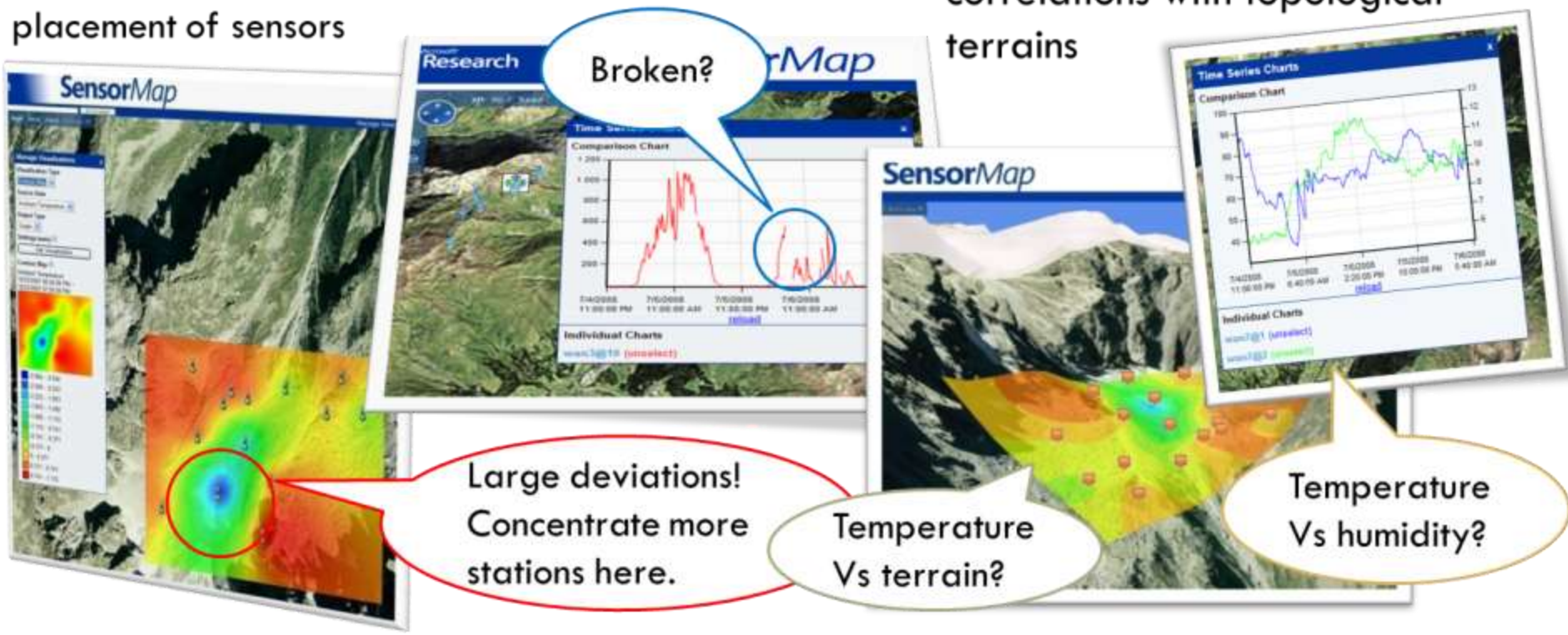
To view sensor layout and visualize measurements in real-time to decide the placement of sensors

Deployment Monitoring

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

Data Analysis

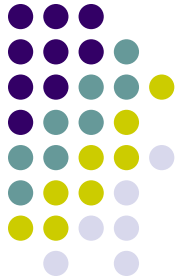
To visualize dependencies among different measurements and correlations with topological terrains



Summary

- SenseWeb is an open platform to share sensor data
  - Scalable , Easy-to-use, Extensible
- Live at http://msra.cn/sensormap/ for AP-area researchers
  - http://research.microsoft.com/en-us/projects/senseweb/

- Call for collaboration on top of SenseWeb, and esp., **mobile sensing** systems and applications



THANKS!