Automated Model-driven Simulation and Visualization of Field Sensor Data

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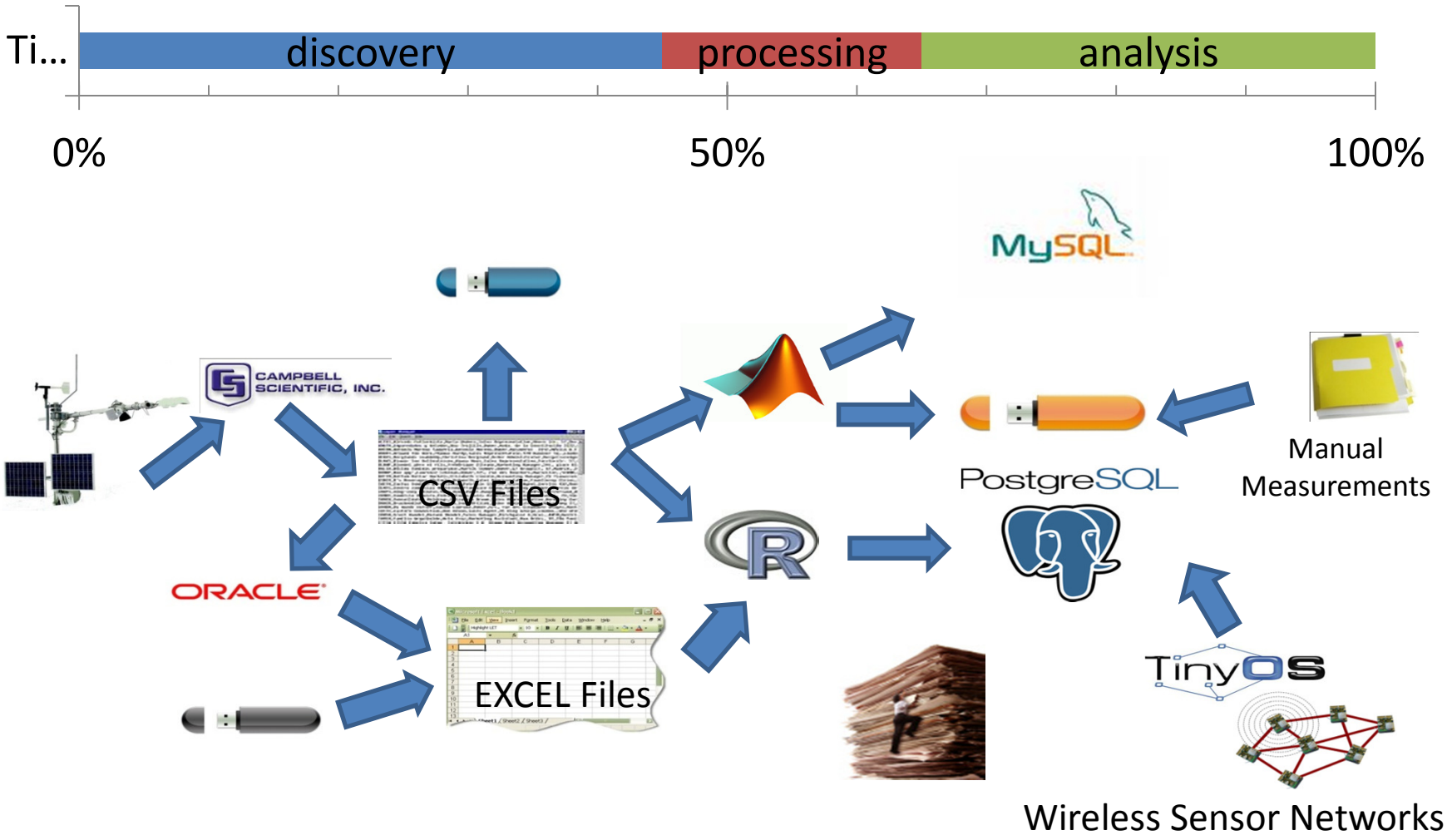
Environmental Data Analysis Lifecycle



EU Hydrosys' objectives

HYDROSYS employs on-site environmental monitoring in case of crisis events:

- identifying key variables of the problem,
- taking fine-grained measurements,

- data and images communication and understanding,
- and validation of a technical solution

Physical Model Simulations

- Environmental models (e.g. GEOtop, Alpine3D) are very useful for understanding complex physical processes and predict potential natural hazards
- Running a model simulation based on field sensor data needs
  - data sensing, aggregation, retrieval, cleaning, interpolation, formatting, model execution and model output visualization

However:

- This process is time-consuming (e.g. only the data preparation for a single simulation typically takes 3-4 days) and highly error-prone, as it involves many manual or semi-automated steps
- The scientists need to employ many different software tools for the various data processing steps, and often manually import data and export the results from them

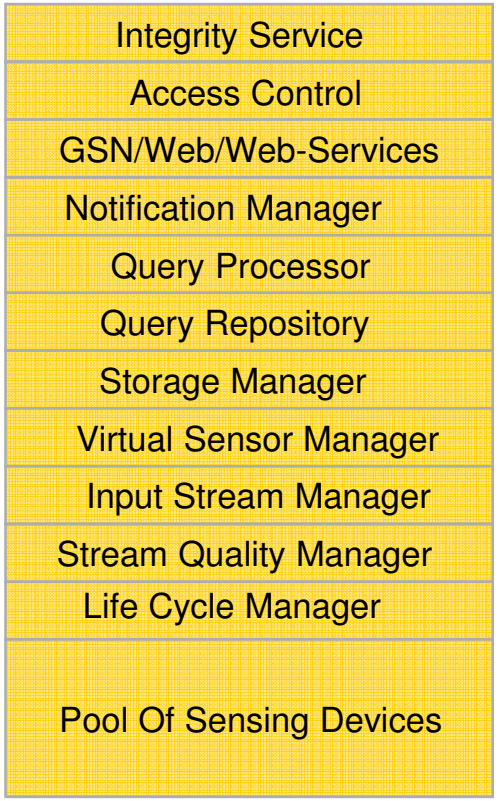
Our Simulation Framework

- A generic data processing and simulation pipeline based on GSN
- Simulation process completely automated, fast and transparent to the scientist
- Simulation tool is fault-tolerant and limits the space for introducing errors
- A scientist can visualize or download sensor data, or run a simulation and obtain the results in the same GUI
- GEOtop model currently employed is, but
  - our approach is generic-enough to consider arbitrary environmental models (Alpine3D integration is under-way)

Global Sensor Networks (GSN)

- Integrates different sensor networks
  - Different abstractions, hard to share
  - Isolated networks, hard to republish
- GSN server:
  - **Goal: Publishing streams generated by sensor networks**
  - Storage, archive
  - Access to sensor network hardware
  - Easy setup, easy to change
- Virtual Sensor:
  - Processing, filtering, aggregation
  - Functional/non-functional properties (storage, filters, etc.)
  - Described in a XML file
- Web service interfaces
  - Fast data retrieval
  - Launch simulation

GSN:
Reference Implementation



GPL License

GSN-R Integration

- R (http://www.r-project.org/) is a popular software package used in the financial, life sciences and environmental sectors
- Java is used as the programming model in GSN for processing tasks (e.g. virtual sensors)
- We extended the programming model to allow GSN to execute R scripts on streaming or static data
- R scripts can perform complex processing and can be executed remotely or locally by GSN

GEOtop, MeteoIO

- GEOtop: *a distributed model of the mass and energy balance of the hydrological cycle for simulations in continuum in small catchments*
  - Open source

- MeteoIO: Data access library (EGU 2010)
  - Several plugins to read data from other formats and protocols (web service interface for GSN, Oracle database, XML format, native Snowpack format)
  - Port data into native formats (e.g. Alpine3D, GEOtop, etc.)
  - Several plugins to output meteorological data
  - Buffering infrastructure (for caching sensor data)
  - Flexible filtering infrastructure (including resampling, accumulating and transparent geographic coordinates conversions)
  - Digital Elevation Models manipulations, spatial interpolation infrastructure
  - Open source

Sensorscope station

GEOtop server

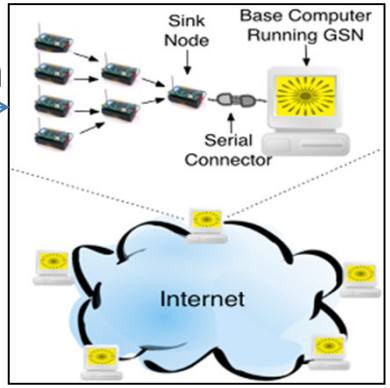
GEOtop virtual sensor

2. Run simulation model based on data

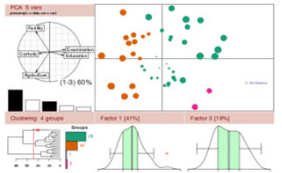
GSN

3. Fetch sensor data

La Fouly deployment



R virtual sensor

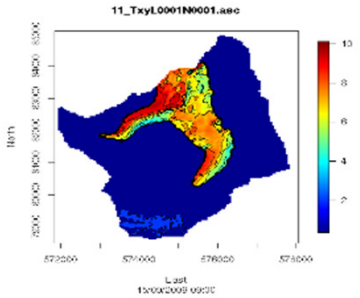


R server

4. Analyze output produce graphs

1. Select sensors Start simulation

5. Observe results



Graphical User Interface

Demo

start

Conclusions

- We offer a simulation framework completely automated, fast and transparent to the scientist
  - Fully-distributed, generic and extensible to arbitrary simulation models
  - Fault-tolerant and limits the space for introducing errors
  - A scientist can visualize or download sensor data, or run a simulation
  - It can run based on historical or real-time data.

- The aforementioned functionality is contributed to the GSN open-source project

- It is currently accessible online (http://lsir-hydrosys01.epfl.ch:22006/) for GEOtop simulations with data obtained from a sensor deployment in La Fouly catchment in Switzerland (Valais) established by EU Hydrosys

- Already implemented for GEOtop and Alpine3D. Arbitrary physical model can be considered for integration

Questions ?

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Links:

- Simulation pipeline (http://lsir-hydrosys01.epfl.ch:22006/)
- EU project Hydrosys (http://www.hydrosysonline.eu)
- GSN (http://sourceforge.net/apps/trac/gsn/)
- MeteoIO (http://slfsmm.indefero.net/p/meteoio/)