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Quality Control of Environmental Measurement Data with Quality Flagging

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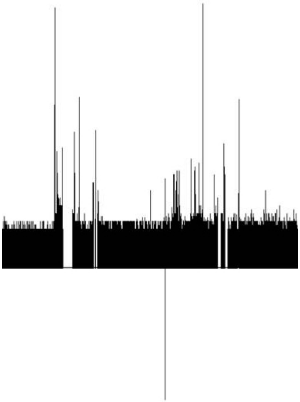
Introduction

- Increased interest in environmental monitoring
  - For process understanding, assess human impact, ...
  - Increasingly automated and large scale
  - Example projects include SMEAR, ICOS, NEON, GLEON
- Measurement, the process, prone to disruptions
- Resulting data often of low quality
- Standard data *representation* models exist, e.g. OGC
  - Attribute `resultQuality` to represent quality (value)
- However,
  - How to *assess* quality?
  - How to assess quality in real-time?

Household water consumption



- Quantity of water consumed between consecutive time points
- Positive values possible
  - Peaks plausible
- Zero values possible
  - Most frequent?
- Negative values make no sense!

Aims

- Discuss quality control of measurement data
  - Using quality flagging
- Implement quality flagging
  - Using an ESB-based software architecture

Quality control of measurement data

- Applications may want quality of individual data point
  - Meaning quality at *dataset* level is insufficient
- In such cases, utilize quality flagging
- With a flagging scheme, such as that of
  - Nordic meteorological institutes[1]
  - Four quality control levels: QC0, QC1, QC2, HQC
  - Ten quality flag values: $0 \ldots 9$
  - Formula to compute overall quality flag
  - Interpretation specific for weather measurements
  - We propose a generic interpretation

Quality control levels

Level	Performed by	Mode
QC0	Device or station	Real-time
QC1	Data acquisition system	Real-time
QC2	Data management system	Batch
HQC	Human operator	Batch

Quality flag values and interpretations

Value	Original interpretation	Generic interpretation
0	No check performed	Value not checked
1	Observation is ok	Approved value
2	Suspected small difference	Suspicious value
3	Suspected big difference	Anomalous value
4	Calculated value	Corrected value
5	Interpolated value	Imputed value
6	(Not defined originally)	Erroneous value
7	(Not defined originally)	Frozen value
8	Missing value	Missing value
9	Deleted value	Deleted value

Quality flag and example data

The quality flag C is computed as follows:

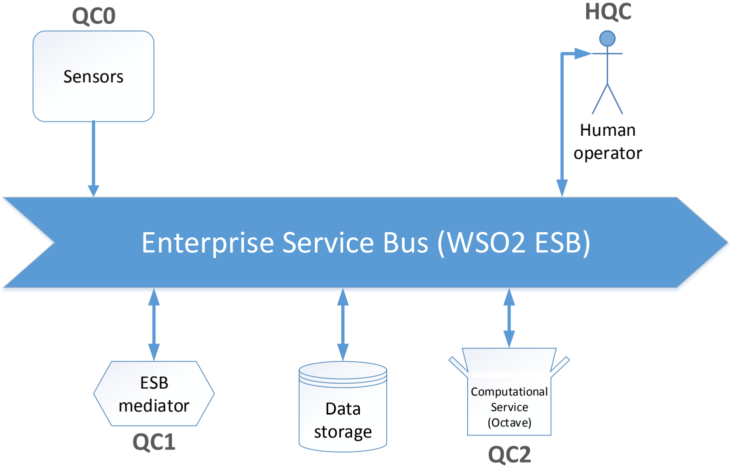
$$C = E_{QC0} + 10 \times E_{QC1} + 100 \times E_{QC2} + 1000 \times E_{HQC}$$

where $E_{QC0}, E_{QC1}, E_{QC2}, E_{HQC}$ are quality flag values for the corresponding quality control level.

time	room temperature	quality flag
2015-03-10T09:30	3.1	9330
2015-03-10T09:30	21.8	4000

9330 = Value not checked by device; anomalous value by data acquisition and management systems; deleted value by human operator. 4000 = Corrected value by human operator.

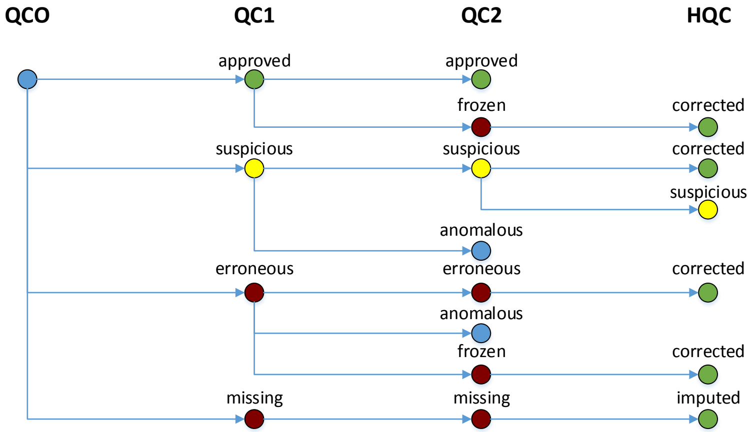
Implement quality flagging



Case study

- Monitoring of residential buildings
- Tested for room temperature and water consumption
- Implemented ESB architecture
- Tested various statistical methods
- Low-cost sensors do not perform QC0
- Instead, QC1 also performs QC0 checks

Room temperature data quality control



Related work

- UncertML[2]
  - Utilized in measurement data quality control[3,4]
  - Proposed also as extension to OGC standards
  - Interoperable representation of probabilistic uncertainties
  - However, uncertainty primarily at dataset level
  - Also, uncertainty $\neq$ quality
- Quality flagging done at device level, e.g. Vaisala

Take aways

- Quality flagging for measurement data quality control
- Requires some flagging scheme
- Advantages of
  - Flagging: individual data point, querying, diagnostics
  - ESB: reconfiguration, data format support, scalability
- Disadvantages
  - Quality flag interpretation is implicit
  - Flags may be too coarse

References

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[2] M. Williams, D. Cornford, L. Bastin, and E. Pebesma. Uncertainty markup language (UncertML), OpenGIS Discussion Paper 08-122r2, Open Geospatial Consortium Inc., 2009.

[3] M. Williams, D. Cornford, L. Bastin, R. Jones, and S. Parker. Automatic processing, quality assurance and serving of real-time weather data, Computers & Geosciences, 37, pp. 351-362, 2011.

[4] M. Williams, D. Cornford, B. Ingram, L. Bastin, T. Beaumont, E. Pebesma, G. Dubois. Supporting interoperable interpolation: the INTAMAP approach. In Proceedings of the In-ternational Symposium on Environmental Software Systems, Prague, 2007.