Data Warehousing for Distributed R&D
Overview and Insights gained

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OFFIS – Institute for Information Technology

International Conference
RAVE 2012
May 8-10, 2012
Bremerhaven, Germany
R&D Institute for ICT

- Associated institute of the Carl von Ossietzky University in Oldenburg
- More than 290 employees (~150 research assistants)
- Established in 1991

R&D Divisions

- Energie (Energy)
- Gesundheit (Health)
- Verkehr (Transportation)
Project Overview

Data Warehouse (DWH)
- Collection and harmonization of energy data
- Data provisioning for research accompanying the alpha ventus offshore wind park
  - Wind turbine (WEA) optimization
  - Environmental impact analysis
- Data access policy enforcement

Storage-Relevant Energy Data
- Secondary data (calibrated sensor data)
- Tertiary data (statistically aggregated data)
- Metadata (data on sensors and tertiary data)
Architecture Overview

**WEDA ETL**
- Central component for sensor data storage and retrieval
- Monitors data input delivery and quality
- Guarantees technical data integrity

**WEDA RUM**
- Role-based user access control

**WEDA Portal**
- Access portal for research partners
- Data exploration and download
## Import Data Volumes

<table>
<thead>
<tr>
<th>Survey „Storage Strategies for Sensor Data in Wind Energy“</th>
<th>alpha ventus DWH</th>
<th>Other (non-wind energy) Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 to 250 sensors</td>
<td>1,500 sensors</td>
<td><em>Data sizes comparable or even greater than those in alpha ventus</em></td>
</tr>
<tr>
<td>5 min to 20 Hz</td>
<td>approx. 75% of the sensors operating at 50 Hz</td>
<td></td>
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<tr>
<td>45,000 to 100,000 metered values per day</td>
<td>4,860,000,000 metered values per day</td>
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<tr>
<td></td>
<td>~18 GByte per day (data value size approx. 4 Byte) and 6.6 TByte per year</td>
<td></td>
</tr>
<tr>
<td>Up to 45,000 values file system-based storage or data base; over 45,000 only file system-based storage</td>
<td>Hybrid (see next slide)</td>
<td></td>
</tr>
<tr>
<td>Volume reduction by compression</td>
<td>Volume reduction by compression</td>
<td></td>
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</tbody>
</table>

*Volume reduction by compression*KIWI-concepts (*Kill it with Iron*)
e.g., [Yuen et al., 2007; Ghemawat et al., 2003]

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Evaluation of Storage Strategies and Design choices for alpha ventus documented in [Beenken et al., 2009]
Hybrid Storage Concept

DWH System (WEDA ETL)

- Extraction
- Staging (Load)
- Workbench
- Transformation
  - Secondary Data Storage Format
  - Tertiary Data Generation

Data Base
- Tertiary Data, References to Secondary Data

File Server
- Secondary Data

Monitoring
- DWH Manager

Data Sources
- Primary Data
- Secondary Data

DWH Portal (WEDA Portal)

Extended DWH Reference Model in accordance with [Bauer and Günzel, 2004]
Use in Transition

User Base and Archive Size

- Linear DWH growth

Number of Users

Size of Archive (TB)
Use in Transition

RAVE projects terminate

Memory upgrade

Increased demand for data sets over large periods of time

Test phase

Number of Downloads

Download Data Size (GB)

- Number of Downloads
- Download Data Size (GB)
Use in Transition

Data delivery input Input and usage
Current Measures

- Download cancellation and wait queue
- Complementary research documents
  - No restriction on file format
  - Upload is curated by OFFIS
- Time stamp calculation for download compilation
  - The frequency of the sensors could not always be met during data recording before delivery to DWH
- Data compression for volume reduction
  - Only data that is older than 1 year
  - On-the-fly decompression upon user queries
  - ~20% compression rate
Project Overview
Data Warehouse
Use in Transition
Current Measures
Insights Gained

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Insights Gained

Continuous Adaptations
• Query optimization and table index updates (cascading change effects)
• Changes to data format specification required changes to the portal and repeated downloads
• Increased demand for data sets over large periods of time required memory upgrade

Local DWH test instance
• Test with representative/real-life data after storage design phase

Tendency to local copies
• If data is available, researcher partners will also want them on their own systems
Insights Gained

Recurring technical data quality issues
- Delivered secondary input data to be stored in the DWH did not always conform to the agreed specification
- Communication overhead

Domain-specific data quality and additional information
- If delivered secondary input data is corrupted, it probably can be resolved automatically by batch processing
  - Batch job can be considered as a part of the sensor → must also be documented and archived
  - Unclear if processed data should replace the corrupted data or if it should be stored separately
  - In general, experimental documentation and data history is highly relevant for future research projects
Outlook

- Progress information for big download compilations
- Thorough use of multithreading
  - e.g., for uploads and download compilation
- Development of a performance laboratory based on the local DWH test instance
- Re-evaluation of DWH-internal storage structures
- Server-side data processing and analysis
  - e.g., standard interfaces for aggregated statistical data
Questions?

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Hybrid Storage Concept

Storage Efficiency
• Secondary data stored in file system
• Tertiary data calculated from secondary data and stored in data base
• Tertiary data references the corresponding secondary data in the file system

Data Handling
• Users can analyse tertiary data before secondary data must be considered and downloaded

Export Optimization
• Secondary data can be downloaded directly
• Users can select subsets of secondary data (queries) according to various parameters; server-side recompilation provides only the relevant data

Long-Term Technology-Independent Storage
• Guaranteed by file system-based secondary data storage in plain CSV format
Import Data Volumes

Some numbers

• 1,500 sensors, approx. 75 % operating in 50 Hz
• 4,320,000 data values per day and 50 Hz sensor
• 4,860,000,000 data values per day