Array Database Assessment WG
Peter Baumann, Kwo-Sen Kuo
2018-mar-23, Berlin, P11
(Spinoff from Big Data IG)

39 members
Structural Variety in Big Data

Stock trading: 1-D sequences (i.e., arrays)

Social networks: large, homogeneous graphs

Ontologies: small, heterogeneous graphs

Climate modelling: 4D/5D arrays

Satellite imagery: 2D/3D arrays (+irregularity)

Genome: long string arrays

Particle physics: sets of events

Bio taxonomies: hierarchies (such as XML)

Documents: key/value stores = sets of unique identifiers + whatever etc.
Structural Variety in Big Data

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- Social networks: large, homogeneous graphs
- Ontologies: small, heterogeneous graphs
- Climate modelling: 4D/5D arrays
- Satellite imagery: 2D/3D arrays (+irregularity)
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etc.
Structural Variety in Big Data

sets + hierarchies + graphs + arrays

sensor, image [timeseries], simulation, statistics data
SERVICE QUALITY
Multi-dimensional arrays play key role in science & engineering & beyond
- Increasingly in focus as „datacubes“
- not supported by SQL nor NoSQL nor NewSQL

Array Databases = modeling + query support for massive arrays
- Server-side evaluation = ship code to data
- Adaptive partitioning, parallelization, distribution, mixed hardware, …

Various tools known – benefits? Maturity? How-tos?
### Expected Impact

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
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<tbody>
<tr>
<td>- Array Databases <strong>not widely known</strong>, FUD about novel paradigm</td>
<td>- Report helps establishing broad knowledge and understanding, “datacubes” getting in focus</td>
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<tr>
<td>- Largely unknown <strong>how to use</strong>, what benefit “datacubes” bring</td>
<td>- Dissemination work supports spread of datacubes, eg, in CEOS &amp; GEOSS</td>
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<td>- Software <strong>choices unclear</strong></td>
<td>- <strong>Large-scale services demonstrate feasibility</strong></td>
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<td>- Lack of datacube <strong>interoperability</strong></td>
<td>- Annotated listing of software + benchmarks <strong>ease selection</strong></td>
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<td>- <strong>Standards getting in place</strong></td>
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<td>- ISO SQL/MDA</td>
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<td>- ISO &amp; OGC “Big Earth Datacube“ stds</td>
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Experimental and operational services, up to 2.5 PB:

- ECMWF/UK - [http://earthserv.ecmwf.int/](http://earthserv.ecmwf.int/)
- PML/UK - [http://earthserv.pml.ac.uk/](http://earthserv.pml.ac.uk/)
- MEEO, IT – [http://eodataservice.org](http://eodataservice.org)
- EOfarm, GR - [http://eofarm.com/](http://eofarm.com/)
- ...plus more emerging, such as HZG, AWI, ...

Standards
Earth Observation Data Service: Cloud-Free Vegetation Index

[system used: rasdaman]
ESA Earth Observation Data Service: Visual Timeseries Analysis
ECMWF: River Discharge
PlanetServer

[system used: rasdaman]
Some Array Database History

[Diedrich et al 2002, using rasdaman; 10,000 satellite images → 1 datacube]
Datacube Federation

```
SELECT ENCODE(CASE
  WHEN (CONDENSE + over i_i in [42364:42368] using
d[0:3600, 0:1800, i_i[0]] / 1423 + 1.47) > ((CONDENSE +
over i_i in [42364:42368] using (c) ['*,*,*,i_i[0]])*(1000))
THEN ((255) * {1c,0c,0c,0c} + (255) * {0c,1c,0c,0c} + (255)
* {0c,0c,1c,0c} + (0) * {0c,0c,0c,1c})

WHEN (CONDENSE + over i_i in [42364:42368] using
d[0:3600, 0:1800, i_i[0]] / 1423 + 4) > ((CONDENSE + over
i_j in [42364:42368] using (c) ['*,*,*,i_j[0]])*(1000))
THEN ((0) * {1c,0c,0c,0c} + (128) * {0c,1c,0c,0c}
```

Query:

Heavy rainfall risk areas

Server:

ECMWF

Run Query
Final Report

- Authors: Peter Baumann, Dimitar Misev, Vlad Merticariu, Bang Pham Huu, Brennan Bell, Kwo-Sen Kuo

- Structure (75 pg):
  - Introduction to Array Databases
  - Array Standards
  - Array Technology
  - Publicly Accessible Array Services
  - Array Systems Assessment
  - Summary

- Where to obtain?
    - Caveat: not complete, not maintained

- Status: public review for adoption as RDA recommendation
19 systems

- **Array Databases**: rasdaman, SciQL, SciDB, EXTASCID, PostGIS Raster, Oracle Geospatial; Teradata Arrays
- **Array tools**: OPeNDAP, xarray, tensorflow, wendelin.core, Google Earth Engine, Open Data Cube, xtensor, boost::geometry, Ophidia, TileDB
- **MapReduce array systems**: SciHadoop, SciSpark

**Feature inspection:**

- Logical model: what data and query model features?
- Physical model: tuning and optimization?
- Architecture: storage, processing, etc.
Final Report
Observations

- Full-stack, clean-slate, C++
  vs
  object-relational add-on
  vs
  scripting language
  - Up to 300x performance difference

- Non-DB tools avoid effort of QL implementation
  - Fixed function calls
  - Missing dynamic optimization opportunities

- Standards in place, but rarely implemented
  - Without standards: Vendor lock-in
    - ISO FDIS SQL / MDA
    - OGC Web Coverage Processing Service (WCPS)
Final Report
Expected Impact

- Increase **uptake** of Array Databases in Science & Engineering
  - in academic and industrial environments
  - Systems, features, benchmarks, deployments, ...

- Datacube **standards** in OGC, ISO, INSPIRE
  - Providing systematic background
  - Active shaping, eg: ISO SQL/MDA (Multi-Dimensional Arrays)
create table LandsatScenes(
  id: integer not null, acquired: date,
  scene: row( band1: integer, ..., band7: integer ) mdarray [ 0:4999,0:4999]
)

select id, encode(scene.band1-scene.band2)/(scene.band1+scene.band2), "image/tiff" 
from LandsatScenes 
where acquired between "1990-06-01" and "1990-06-30" and 
  avg( scene.band3-scene.band4)/(scene.band3+scene.band4)) > 0
ISO SQL MDA („Multi-Dimensional Arrays“) - FDIS
ISO 19123-2 Coverage Implementation Schema - IS
ISO 19123-1 Coverage Abstract Model - under work
ISO 19163-2 imagery and gridded data - IS (contributed)
OGC Coverage Implementation Schema 1.1 - IS
OGC Web Coverage Service 2.1 - under adoption
OGC WCS REST Protocol Binding 1.0 - under adoption
INSPIRE WCS Download Service - adopted
ADA:WG

Summary

- 39 members
- 12,000+ Wiki hits
- Adopters:
  - Petascale services
  - Visible contribution to datacube standards in ISO, OGC, INSPIRE
- Contributions:
  - First large-scale, systematic investigation
    - Functionality, performance, tuning, standards
  - Systematics
  - Decision support

Thanks to all who contributed to this huge effort!
Final Report

Motion

- The Array Database Assessment Working Group recommends to the RDA Council to adopt the Array Database Report as endorsed RDA Recommendation.
- Moved by: Peter Baumann
- Second: Morris Riedel
- Vote: no objection to unanimous consent