Datacubes on Steroids with ISO Array SQL

FOSDEM 2017, Brussels
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(co-funded through EU EarthServer-2)
Jacobs MSc in Data Engineering

Machine Learning – Big Data – Cloud Computing – Visualization – and more...

all-English, international campus – research involvement – strong industry connections
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

- arrays
- graphs
- arrays
- arrays
- sets
- hierarchies
- sets
Structural Variety in Big Data

- sensor, image [timeseries], simulation, statistics data

- sets + hierarchies + graphs + arrays
Array SQL

Information technology — Database languages — SQL —

Part 15:
Multi-Dimensional Arrays (SQL/MDA)

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.nband1+scene.band2), „image/tiff“
from LandsatScenes
where acquired between „1990-06-01“ and „1990-06-30“ and
    mdavg( scene.band3-scene.band4)/(scene.band3+scene.band4)) > 0
Linear Algebra

- Matrix multiplication

\[
(AB)_{ij} = \sum_{k=1}^{m} A_{ik} B_{kj}
\]

```sql
select mdarray i in [0:m], j in [0:p]
    elements condense +
    over k in [0:n]
    using a [ i, k ] * b [ k, j ]
from   matrix as a, matrix as b
```

- Histogram

```sql
select mdarray bucket in [0:255]
    elements mdcount( img = bucket )
from   img
```
rasdaman

= „raster data manager“: SQL+ n-D arrays
  - Scalable parallel “tile streaming” architecture

- Mature, in operational use, on OSGeo Live
  - Ex: [www.planetserver.eu](http://www.planetserver.eu)

- ESA 2017: “world leading environment”, “standard working horse for OGC standardisation on these innovative data access interfaces”
Adaptive Partitioning („Tiling“)

- Any tiling, canned into strategies [ICDE 1999]
  - 250+ TB datacubes

- rasdaman storage layout language [IEEE SSTDM 2010]

```sql
insert into MyCollection
values ... 
tiling
  area of interest [0:20,0:40], [45:80,80:85]
tile size 1000000
index d_index storage array compression zlib
```
Adaptive Partitioning („Tiling“)

- Any tiling, canned into strategies [ICDE 1999]
  - 250+ TB datacubes

- Why irregular tiling?

[OpenStreetMap]

[Centrella et al: scidacrevews.org]
Parallel, Distributed Processing

1 query → 1,000+ cloud nodes
[ACM SIGMOD DanaC 2014]
[VLDB BOSS 2016]

select 
  max((A.nir - A.red) / (A.nir + A.red)) 
  - max((B.nir - B.red) / (B.nir + B.red)) 
  - max((C.nir - C.red) / (C.nir + C.red)) 
  - max((D.nir - D.red) / (D.nir + D.red)) 
from A@A, B@B, C@C, D@D
Architecture

Web clients (m2m, browser)

Internet

rasdaman

geo services

rasserver

File system

database

distributed query processing
No single point of failure

alternative storage
Hadoop/Spark – one size does not fit all

- “Since it was not originally designed to leverage the structure its performance is suboptimal” [Daniel Abadi]
- U Madison, GMU benchmark confirms [AGU 2015]

EarthServer: Datacubes At Your Fingertips

- Agile Analytics on x/y/t + x/y/z/t Earth & Planetary datacubes
  - EU rasdaman + NASA WorldWind

- Global data federation
  - 250+ TB → 1+ PB

- Intercontinental initiative, 3+3 years:
  EU + US + AUS

www.earthserver.eu
Domains Investigated

- **Geo**
  - Environmental sensor data, 1-D [Sensors 2009]
  - Satellite / seafloor maps, 2-D [VLDB 1999, 2003, ...]
  - Geophysics (3-D x/y/z)
  - Climate modelling (4-D, x/y/z/t) [DB Spektrum 2012]

- **Life science**
  - Gene expression simulation (3-D) [InfSys 2003]
  - Human brain imaging (3-D / 4-D) [TiNS 2001]

- **Other**
  - Computational Fluid Dynamics (3-D)
  - Astrophysics (4-D)
  - Statistics (n-D)
OSGeo Experiences & Thoughts

- Opportunities for improvement, based on:
  - OSGeo Charter Member
  - Executed project incubation procedure with rasdaman
  - Since 2008 engaged in open-source software
OSGeo Experiences & Thoughts

- Opportunities for improvement

- Organizational Maturity: Process definition & implementation, QM
  - No inventory of decisions taken
  - Incubation management: pyWPS 8 years; rasdaman 6.5 years
  - Apply incubation criteria to itself (first)
  - In elections, typically insiders recommend each other
OSGeo Experiences & Thoughts

- Opportunities for improvement
- Organizational Maturity: Process definition & implementation, QM
- Focus on Core Mission
  - Should brand „good software“, not conquer project
  - „design by committee“ over „expert leadership“
OSGeo Experiences & Thoughts

- Opportunities for improvement
- Organizational Maturity: Process definition & implementation, QM
- Focus on Core Mission

- Dogmatic „Software Communism“
  - „all software free“ - why?
  - Large companies don‘t care, small companies vulnerable
  → Need inclusive approach
Wrap-Up

„One cube says more than a million images“

- ISO SQL/MDA candidate standard
- Array Databases bring flexibility + scalability
- rasdaman community
  - OGC, INSPIRE WCS reference implementation
  - blueprint for „Big Data“ standards
- FOSS needs to be inclusive