Datacubes as an Enabling „Big Data“ Paradigm

Prof. Dr. Peter Baumann
Jacobs University Bremen
Why Datacubes?
Archives Are Not Analysis-Ready

- Divergent access patterns for ingest and retrieval
- Server must mediate between access patterns
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

- 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

sensor, image [timeseries], simulation, statistics data

sets + hierarchies + graphs + arrays
SERVICE QUALITY
„What You Get is What You Need“
rasdaman
rasdaman: Agile Datacube Analytics

= „raster data manager“: SQL + n-D arrays

- Mature, in operational use, open source
  - blueprint for ISO Array SQL, OGC WCPS, ...

“world leading environment”, “standard working horse for OGC standardisation on these innovative data access interfaces“
- G. Landgraf, ESA, 2017
select
  encode(
    struct {
      red: (char) s.b7[x0:x1,x0:x1],
      green: (char) s.b5[x0:x1,x0:x1],
      blue: (char) s.b0[x0:x1,x0:x1],
      alpha: (char) scale( d, 20 )
    },
    "image/png"
  )
from SatImage as s, DEM as d

[JacobsU, Fraunhofer; data courtesy BGS, ESA]
Linear Algebra Ops

- **Matrix multiplication**

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

- **Histogram**

  ```
  select marray bucket in [0:255]
  values count_cells( img = bucket )
  from img
  ```

- **All ops defined through Array Algebra**
  - marray, condense
...But That‘s Not What You Want to See

- Users should stay in their comfort zone
  - navigation: Web client; ...; analytics: python, R, ...

```python
>>> con = Connection(hostname="127.0.0.1", port=7001)
>>> mr = RasCollection(con, "mr")
>>> mr = mr[100,150] # Array Subsetting
>>> mr += 1
>>> mr = mr ** 2 # Square of all elements
>>> mr = mr. filter (oid=2)
>>> mr.query
<RasQueryObject>
>>> str (mr.query)
"Select exp(mr[100,150]+1,2) from mr where oid(mr) = 2"
>>> arr = mr.eval ()
<RasArrayObject>
>>> arr.to_array () # Default conversion : Numpy Array
[[ [...], [...], [...]]]
Adaptive Partitioning („Tiling“)

- Any tiling [Furtado 1999]
  - Cast into strategies
  - rasdaman storage layout language

- Why irregular tiling?

```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
```

[OpenStreetMap]
Architecture

Web clients (m2m, browser)

Internet

rasdaman
geo services

rasserver

file system
database

external files

Optional compression

distributed query processing
No single point of failure

alternative storage

[SSTD 2013]
Parallel, Distributed Processing

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, B, C, D

1 query → 1,000+ cloud nodes
[ACM SIGMOD DanaC 2014]
[VLDB BOSS 2016]
The EarthServer Example
Intercontinental initiative: EU + US + AUS, 3+3 years, since 2011

Agile Analytics on 3D, 4D Earth & Planetary datacubes
  - 500+ TB sites now, next: 1+ PB
  - EU rasdaman + US NASA WebWorldWind

Towards federation: single common information space

Transparent Federation

SELECT ENCODE(CASE
WHEN (CONDENSE + over I in [42364:42368] using
  d[0:3600, 0:1800, I][0]] / 1423 + 1.47) > ((CONDENSE +
over I in [42364:42368] using (c) *[***,***,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 in [42364:42368] using
  d[0:3600, 0:1800, I][0]] / 1423 + 4) > ((CONDENSE + over
I in [42364:42368] using (c) *[***,***,I][0]]*(1000))
THEN ((0) *(1c,0c,0c,0c) + (128) *(0c,1c,0c,0c) + (255)
  *(0c,0c,1c,0c) + (255) *(0c,0c,0c,1c))

WHEN (CONDENSE + over I in [42364:42368] using
  d[0:3600, 0:1800, I][0]] / 973) > ((CONDENSE + over
I in [42364:42368] using (c) *[***,***,I][0]]*(1000))
THEN ((0) *(1c,0c,0c,0c) + (64) *(0c,1c,0c,0c) + (64)
  *(0c,0c,1c,0c) + (255) *(0c,0c,0c,1c))

Query:

- Heavy rainfall risk areas

Server:

ECMWF

Helmholtz Open Science Webinars
Webinar 41 – 12 / 16 June 2017
German recommendations for Roadmap

EO Big Data

- Establish „European Datacube Federation“ as a strategic goal
  - Advancing user service quality, specifically: timeseries analytics
  - Enable flexible framework for value-adding services, through open standards
  - Maintain European technology lead
  - EarthServer as reference example to be enlarged

- Foster and Organize joint activities with platform developers and operators in member states
  - Analyse existing EO Expolitation Platforms with respect to common functions and interoperable interfaces
  - Define federation requirements including IT security aspects on appropriate levels
  - Support harmonization and standardization on interfaces of federated platforms
  - Develop components and workflows supporting harmonized scenarios and interfaces
Standards & Related
ISO Array SQL

```
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
    avg( scene.band3-scene.band4)/(scene.band3+scene.band4)) > 0
```
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)
Related Work: Hadoop – *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]

**COMMON SENSE**
Just because you can, doesn't mean you should.
RDA Array Database Assessment WG

- Spinoff from Big Data IG
  - Chairs: Peter Baumann, Kwo-Sen-Kuo

- **Mission:** to provide support for technologists and decision makers
  - in academic and industrial environments

- **Approach:** neutral, thorough hands-on evaluation
  - Feature comparison, benchmarks, deployments at scale

- **Value proposition:** aid data scientists & engineers in question: [how] can we benefit from Array Database technology?
Conclusion
Conclusion

- Spatio-temporal datacubes major „Big Data“ category in sci & eng
  - *sensor, image (timeseries), simulation, statistics data*

- rasdaman datacube engine:
  - More user friendly, better performance & scalability
  - Mature, operational on 500+ TB, standards blueprint

- See us: [www.rasdaman.org](http://www.rasdaman.org), [www.jacobs-university.de/lsis](http://www.jacobs-university.de/lsis)

„A cube says more than a million images“