EarthServer: Half a Petabyte flocking around an Array Analytics Engine

XLDB, Stanford, 2012-sep-11

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A Brief History of Array DBMSs

First appearance in literature (not first implementation)

Something wrong/missing? Let us know!
Array DB Research @ Jacobs U

- Large-Scale Scientific Information Systems research group
  - focus: large-scale n-D raster services & beyond
  - www.jacobs-university.de/lsis

- Spin-off company: rasdaman GmbH

- Main results:
  - Array DBMS, rasdaman
  - Geo service standards: Chair, OGC raster-relevant working groups, editor of 10+ stds & candidate stds
    - Geo Array QL standard (adopted)
  - Further: Array SQL
EarthServer: *Big Earth Data Analytics*

- Scalable On-Demand Analytics & Fusion for all Earth Sciences
  - 7 mUS$ budget, 11 partners, 3 years
  - Based on rasdaman
  - Federated query processing, integrated data/metadata search, 3D clients

- 6 * 100+ TB databases for all Earth sciences + planetary science

Cryospheric Science
- landcover mapping

Airborne Science
- high-altitude long-endurance drones

Atmospheric Science
- climate variables

Geology
- geological models

Oceanography
- marine model runs + in-situ data

Planetary Science
- Mars geology
The rasdaman Array DBMS

- Goal: massive n-D Sensor, Image, Model, & Statistics DB
  - [Baumann 1992, Baumann VLDBJ 1994, ...]

- declarative, minimal, safe Array Algebra:
  - Intensive user studies: statistics, image, signal processing

- Minimally invasive DBMS integration
  - new attribute type: array<celltype,extent>

- SQL-embedded DML with array operators
  - select / insert / update / delete + „partial update“

```sql
select img.scene.green[x0:x1,y0:y1] > 130
from LandsatArchive as img
where some_cells( img.scene.nir > 127)
```

- Web mapping, image & signal processing, statistics, linear algebra, pattern mining, scientific analytics
Tiled Array Storage

- **Goal:** faster loading by tuning storage pattern to workload
  - Tiles stored in BLOBs = unit of disk access

- **Tiling classification** [Furtado+ 1999]
  based on degree of alignment
  - Cool idea: overlapping tiles [SciDB 2010]

```
regular   irregular   partially aligned   totally nonaligned
aligned   nonaligned
```
Query Processing: Overview

- Clear separation: set vs array trees
- Extensive optimization
- Tile-based evaluation

\[
\text{select } a < \text{avg}\_\text{cells}( b + c ) \\
\text{from } a, b, c
\]
QP in a Federation

- Heterogeneous WCPS peer networks
- Manifold criteria possible: data location, minimal transport, current load, ...

for $a$ in (A), $b$ in (B)
return encode(
  
  ( ($a.nir - a.red) / (a.nir + a.red) 
  - ($b.nir - b.red) / (b.nir + b.red) ), "HDF5"
)

for $a$ in (A)
return encode(
  
  ($a.nir - a.red) / (a.nir + a.red),
  "array-compressed"
)

for $b$ in (B)
return encode(
  
  ($b.nir - b.red) / (b.nir + b.red),
  "array-compressed"
)

[Owonibi 2012]
Optimizations Investigated

- Adaptive tiling
- Adaptive compression
- Multi-dimensional indexing
- Distributed query processing
- Query rewriting
- Pre-aggregation
- Physical operator clustering
- Transparent tape integration
- Just-in-time compilation
- GPU processing
- Tile caching
- ...

CU @ poster!
Summary: Domains Investigated

- **Geo**
  - Environmental sensor data, 1-D
  - Satellite / seafloor maps, 2-D
  - Geophysics (3-D x/y/z)
  - Climate modelling (4-D, x/y/z/t)

- **Life science**
  - Gene expression simulation (3-D)
  - Human brain imaging (3-D / 4-D)

- **Other**
  - Computational Fluid Dynamics (3-D)
  - Astrophysics (4-D)