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Arrays in database systems, the next frontier ?

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What is an array?

An **array** is a systematic arrangement of objects, usually in rows and columns.

Get(A, X, Y) => Value

Set(A, X, Y) <= Value

There are many species: Bit array, dynamic array, parallel array, sparse array, variable length array, jagged array

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Who needs them anyway ?

Seismology – partial timeseries (temporal lists)

Climate sim – temporal ordered grid snapshots

Astronomy - temporal ordered rasters

Remote sensing - ,,

Social networks – 2-D user profiling

Genomics – ordered DNA strings

Scientists 'love them' :

MSEED, NETCDF, FITS, CSV

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Arrays in DBMS

There was no direct economic value in arrays.

Astral (1980), Plain (1980)

Relational prototype built on arrays (1975)

Object-orientation and persistent languages were the make belief to handle them

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Postgresql

Array declarations:

CREATE TABLE sal_emp (name text, pay_by_quarter integer[], schedule text[][]);

CREATE TABLE tictactoe (squares integer[3][3]);

Array operations: denotation ([]), contains (@>), is contained in (<@), append, concat (||), dimension, lower, upper, prepend, to-string, from-string

Mysql

From the MySQL forum May 2010:

“

> How to store multiple values in a single field? Is there any array data type

➢concept in mysql? >

As Jörg said "Multiple values in a single field" would be an explicit violation of the relational model..."

“

Is there any experience beyond encoding it as blobs?

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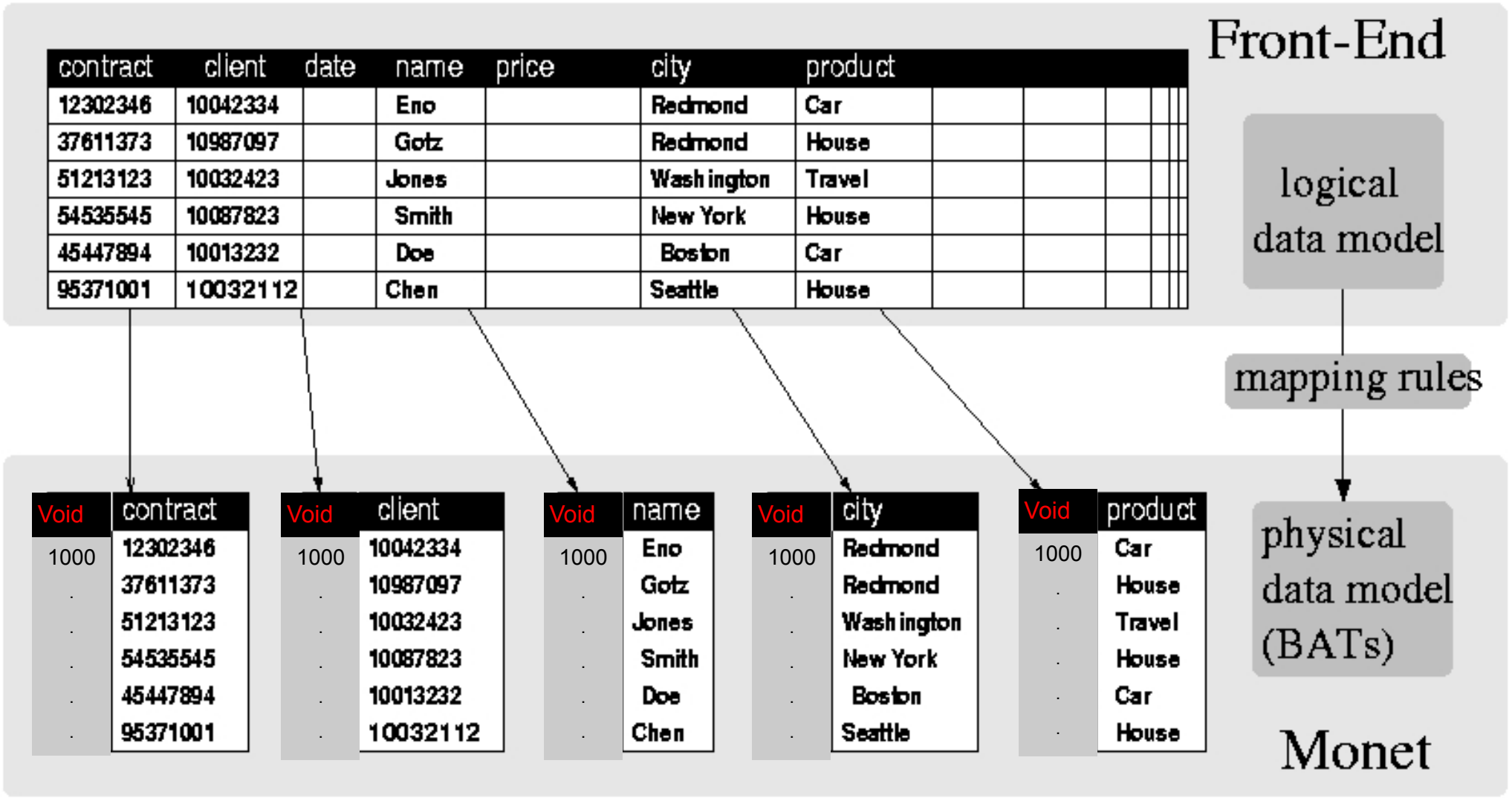
What is the problem?

- Appropriate array denotations?
- Functional complete operation set ?
- Scale ?
- Size limitations due to (blob) representations ?
- Community awareness?

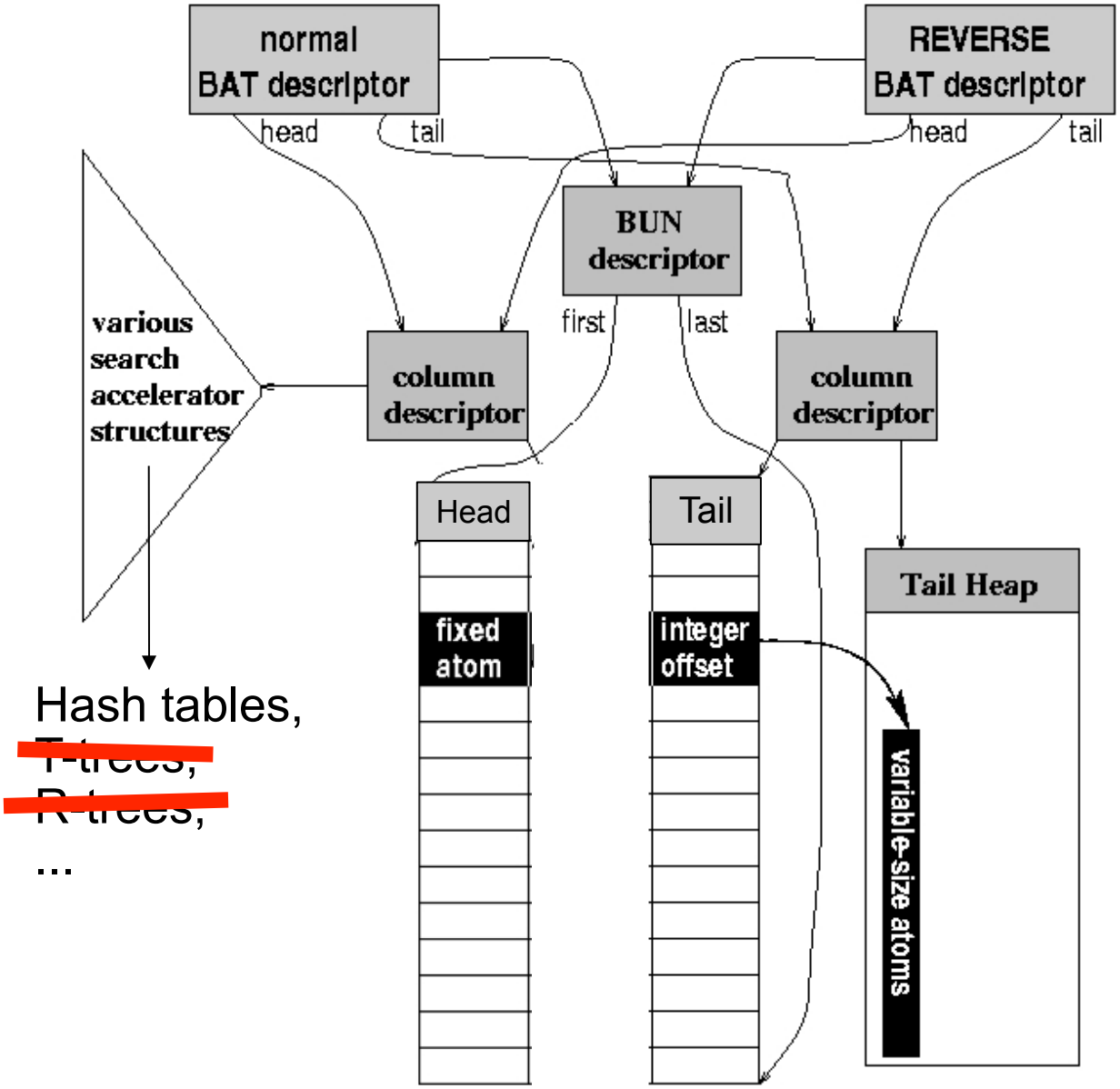
  - Raster data (Peter Baumann)
  - Event data (Tore Rish)
  - Microscopy data (Jennie Zhang)

Storing Relations in MonetDB



Virtual OID: seqbase=**1000** (increment=1)

BAT Data Structure



BAT:
binary association table

BUN:
binary unit

Head & Tail:
- consecutive memory blocks (arrays)
- memory-mapped files

Tail Heap:
- best-effort duplicate elimination for strings (~ dictionary encoding)

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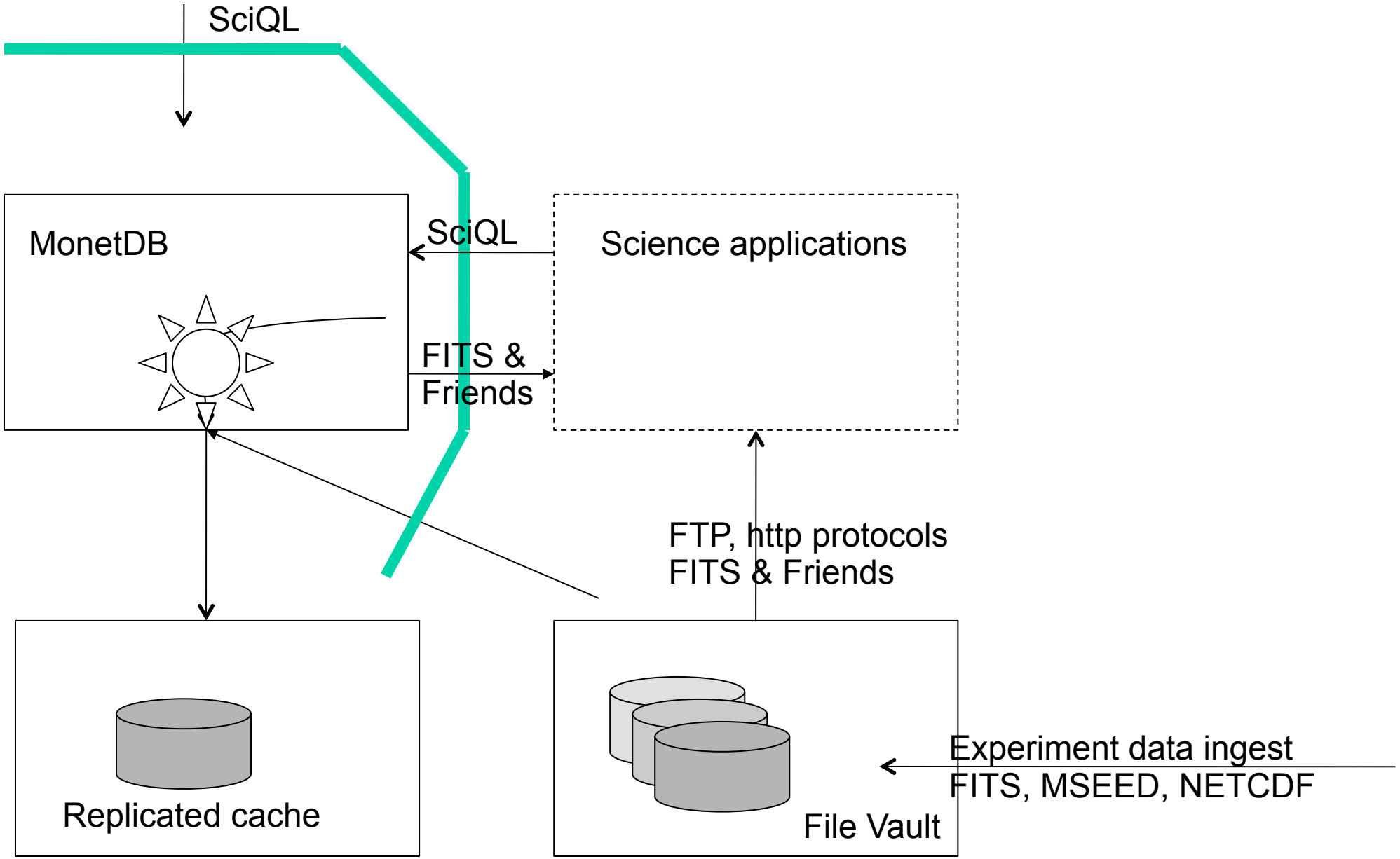
MonetDB Vaults

A contract between MonetDB and file repository of voluminous scientific data

- provide seamless SQL access to foreign file formats using SciQL views
- zero cost, adaptive loading and replication
- Capitalize libraries as UDFs (linpack, R,..)
- Short term targets:
  - MSEED, FITS, NETCDF, csv

Vaults


SciQL
MonetDB
SciQL
Science applications
FITS &
Friends
FTP, http protocols
FITS & Friends
Replicated cache
File Vault
Experiment data ingest
FITS, MSEED, NETCDF

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SciQL

(called Cycle)

Work in Progress !

Martin Kersten

Niels Nes

Milena Ivanova

Ying Zhang

2010 DIR Workshop, Edinburgh

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MonetDB SciQL

SciQL (*pronounced 'cycle')*

- A backward compatible extension of SQL'03
- Symbiosis of relational and array paradigm
- Flexible structure-based grouping
- Capitalizes the MonetDB physical array storage
  - Recycling, an adaptive 'materialized view'
  - Zero-cost attachment contract for cooperative clients

http://www.cwi.nl/~mk/SciQL.pdf

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SciQL examples

```
CREATE ARRAY matrix (
    x integer DIMENSION[0:4],
    y integer DIMENSION[0:4],
    value float DEFAULT 0 );
```

```
CREATE ARRAY vmatrix (
    x integer DIMENSION[-1:5],
    y integer DIMENSION[-1:5],
    value float DEFAULT 0 );
```

```
-- simple checker boarding aggregation
SELECT sum(value) FROM matrix WHERE (x + y) % 2 = 0

-- embedding a transposed into a zero enlarged one
INSERT INTO vmatrix  SELECT [y], [x], value  FROM matrix
```

SciQL tiling examples

-- structural aggregation

```
SELECT x, y, avg(value) FROM matrix
GROUP BY matrix[x:x+2][y:y+2];
```

```
SELECT x, y, avg(value) FROM matrix
GROUP BY DISTINCT matrix[x:x+2][y:y+2];
```

```
SELECT x, y, avg(value) FROM vmatrix
GROUP BY matrix[x-1:x+1][y-1:y+1];
```

```
SELECT x, y, avg(value) FROM vmatrix
GROUP BY matrix[x][y],
   matrix[x-1][y], matrix[x+1][y],
   matrix[x][y-1], matrix[x][y+1];
```

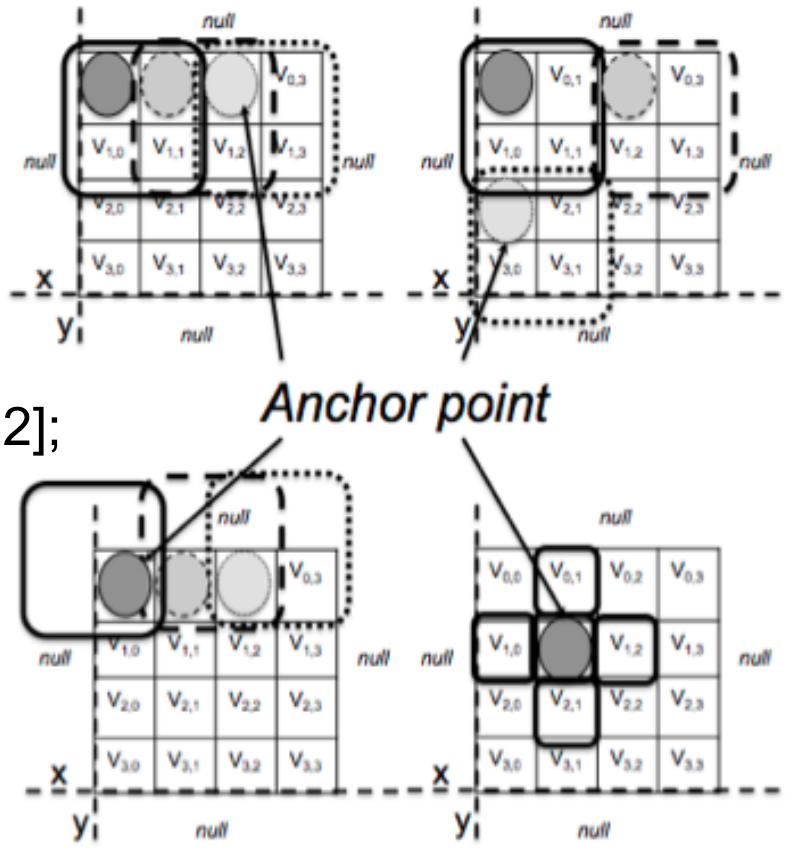

Figure 3: SciQL Array Tiling

SciQL storage examples

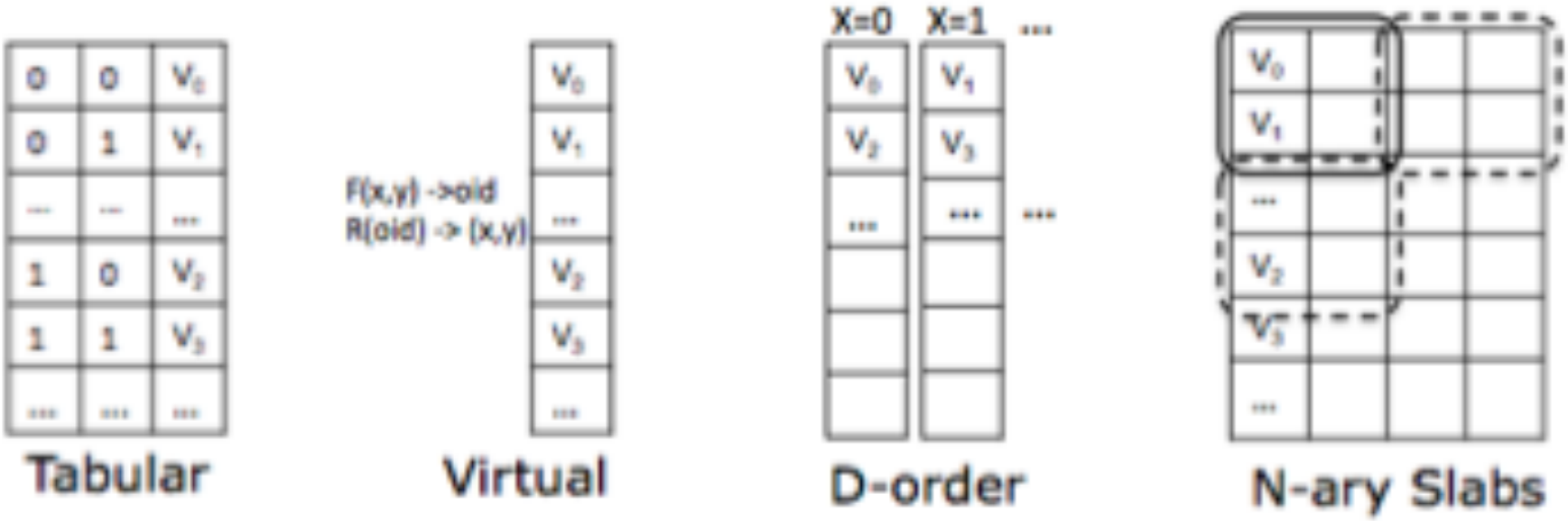

Figure 1: Alternative Array Storage Schemes

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Science DBMS

MonetDB

	MonetDB 5.23	SciDB 0.5	Rasdaman
Open source	Mozilla License	GPL 3.0 Commercial	Dual license
Downloads	>12.000 /month	Tens up to now	
SQL compliance	SQL 2003	??	SQL92++
Interoperability	JDBC, ODBC, MAPI, C, Python, Ruby, C++	C++ UDF	
Array model	SciQL	AQL	RASQL
Science support	Linked libraries	Linked libraries	Linked libraries
Foreign files	Vaults of csv, FITS, NETCDF, MSEED	??	
Distribution	50-200 node cluster	4 node cluster	
Distribution tech	Dynamic partial replication	Static fragmentation	Static fragmentation
	Various schemes	Map-reduce	
Largest demo	Skyserver SDSS 6 3TB	---	

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Minimal requirements?