NoSQL & NewSQL

With material by Willem Visser

Overview

- NoSQL
- Transactions
- NewSQL

NoSQL

CONSTRUCTOR UNIVERSITY

Performance Comparison

- On > 50 GB data:
- MySQL
  - Writes 300 ms avg
  - Reads 350 ms avg
- Cassandra
  - Writes 0.12 ms avg
  - Reads 15 ms avg

We Don‘t Want No SQL !

- NoSQL movement: SQL considered slow → only access by id („lookup“)
  - Deliberately abandoning relational world: „too complex“, „not scalable“
  - No clear definition, wide range of systems
  - Values considered black boxes (documents, images, ...)
  - simple operations (ex: key/value storage), horizontal scalability for those
  - ACID → CAP, „eventual consistency“
- Systems
  - Open source: MongoDB, CouchDB (documents), Cassandra, HBase (columns), Riak, Redis (key/values)
  - Proprietary: Amazon, Oracle, Google , Oracle NoSQL
- See also: http://glennas.wordpress.com/2011/03/11/introduction-to-nosql-john-nunemaker-presentation-from-june-2010/

NoSQL

- Previous „young radicals“ approaches subsumed under „NoSQL“
- = we want „no SQL“
- Well...„not only SQL“
  - After all, a QL is quite handy
  - So, QLs coming into play again (and 2-phase commits = ACID!)
- Ex: MongoDB: „tuple“ = JSON structure

```
db.inventory.find(
  {   type: 'food',
      $or: [ { qty: { $gt: 100 } }, { price: { $lt: 9.95 } } ]
  }  )
```

Another View: 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.

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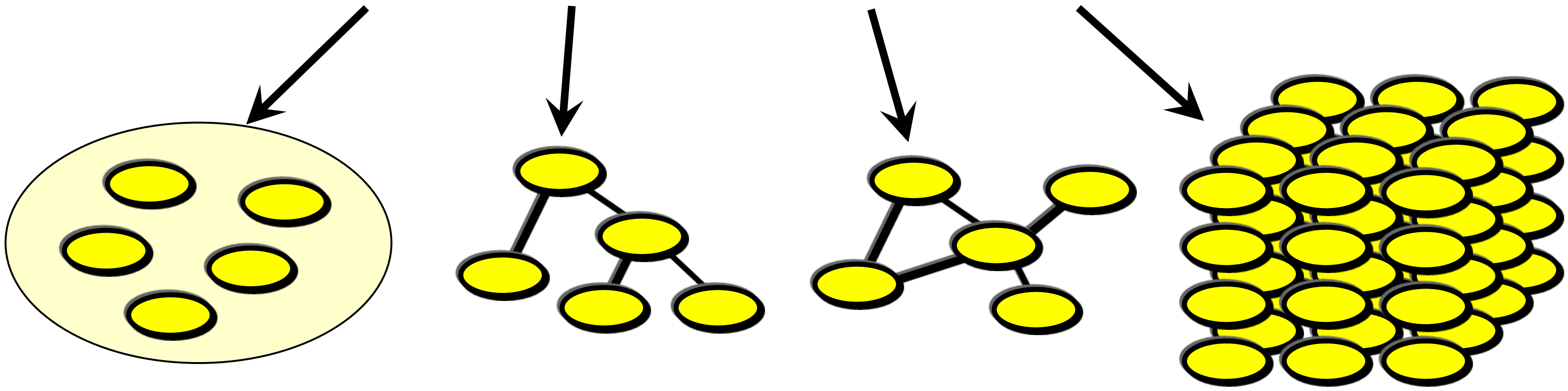
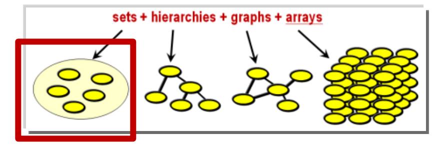
- etc.

Structural Variety in [Big] Data

sets + hierarchies + graphs + <u>arrays</u>

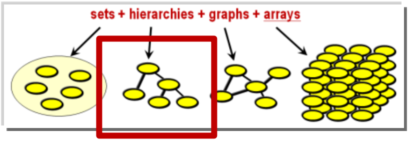


Ex 1: Key/Value Store



- Conceptual model: key/value store = set of key+value
  - Operations: *Put(key,value), value = Get(key)*
  - → large, distributed hash table
- Needed for:
  - twitter.com: tweet id -> information about tweet
  - kayak.com: Flight number -> information about flight, e.g., availability
  - amazon.com: item number -> information about it
- Ex: Cassandra (Facebook; open source)
  - Myriads of users, like:

Ex 2: Document Stores

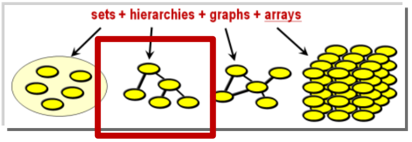


- Like key/value, but value is a complex document
  - Data model: set of nested records
- Added: Search functionality within document
  - Full-text search: Lucene/Solr, ElasticSearch, ...
- Application: content-oriented applications
  - Facebook, Amazon, …
- Ex: MongoDB, CouchDB

```
db.inventory.find( { $or: [ { status: "A" }, { qty: { $lt: 30 } } ] } )
```

```
SELECT * FROM inventory WHERE status = "A" AND qty < 30
```

Ex 3: Hierarchical Data




```xml
<?xml version="1.0" encoding="UTF-8"?>

<bookstore>

<book category="COOKING">
  <title lang="en">Everyday Italian</title>
  <author>Giada De Laurentiis</author>
  <year>2005</year>
  <price>30.00</price>
</book>

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  <author>J K. Rowling</author>
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  <author>Per Bothner</author>
  <author>Kurt Cagle</author>
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  <author>Erik T. Ray</author>
  <year>2003</year>
  <price>39.95</price>
</book>

</bookstore>
```

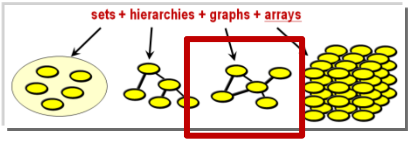
- Disclaimer: long before NoSQL!

```
doc("books.xml")/bookstore/book/title
```

```
doc("books.xml")/bookstore/book[price<30]
```

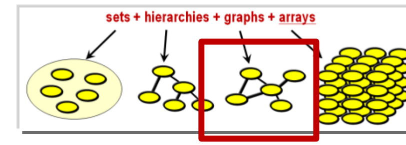
- Later more, time permitting!

Ex 4: Graph Store

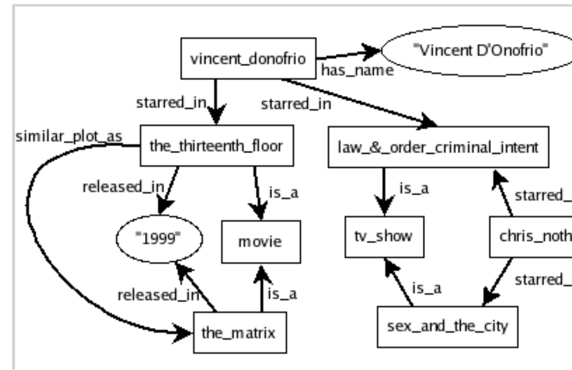


- Conceptual model: Labeled, directed, attributed graph
- Why not relational DB? can model graphs!
  - but “endpoints of an edge” already requires join
  - No support for global ops like transitive hull
- Main cases:
  - Small, heterogeneous graphs
  - Large, homogeneous graphs

Ex 4a: RDF & SPARQL

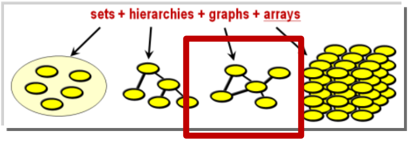


- Situation: Small, heterogeneous graphs
- Use cases: ontologies, knowledge graphs, Semantic Web
- Model:
  - Data model: graphs as triples
    → RDF (Resource Data Framework)
  - Query model: patterns on triples
    → SPARQL (see later, time permitting)




```
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
SELECT ?name ?mbox
WHERE
    {
        ?x foaf:name ?name .
        ?x foaf:mbox ?mbox
    }
```

Ex 4b: Graph Databases

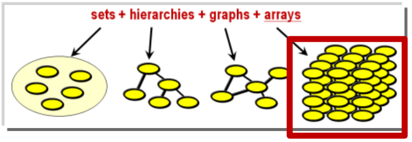


- Situation: Large, homogeneous graphs
- Use cases: Social Networks

- Common queries:
  - *My friends*
  - *who has no / many followers*
  - *closed communities*
  - *new agglomerations,*
  - *new themes, ...*
- Sample system: Neo4j with QL Cypher

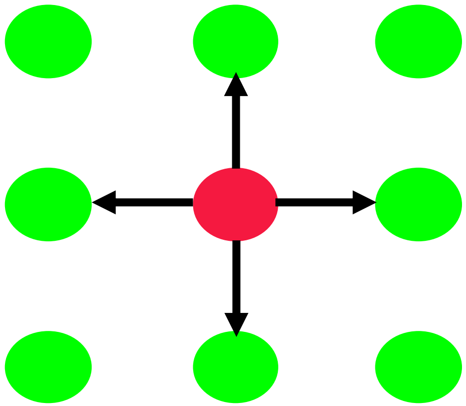
```
MATCH (:Person {name: 'Jennifer'})-[:WORKS_FOR]->(company:Company)
RETURN company.name
```

Ex 5: Array Analytics

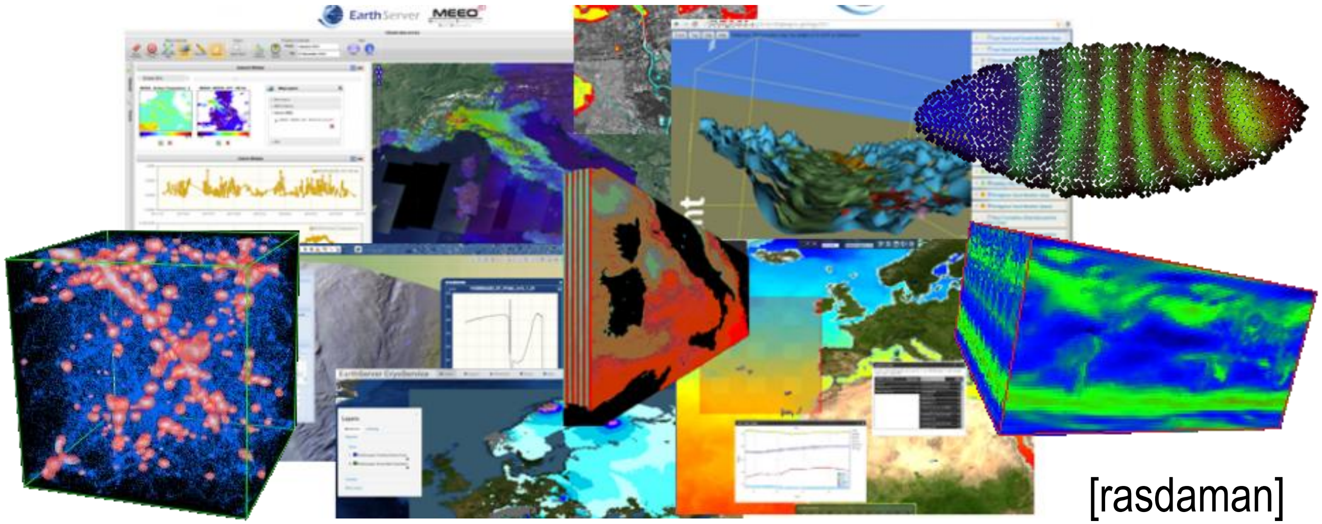


- **Array Analytics** :=
  Efficient analysis on multi-dimensional arrays of a size several orders of magnitude above the evaluation engine's main memory

sensor, image [timeseries], simulation, statistics data

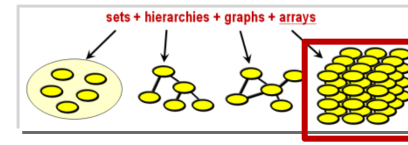


- Essential property: *n*-D Cartesian neighborhood



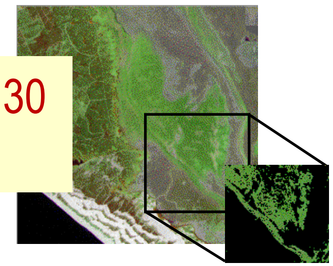
[rasdaman]

Ex 5: Array Databases

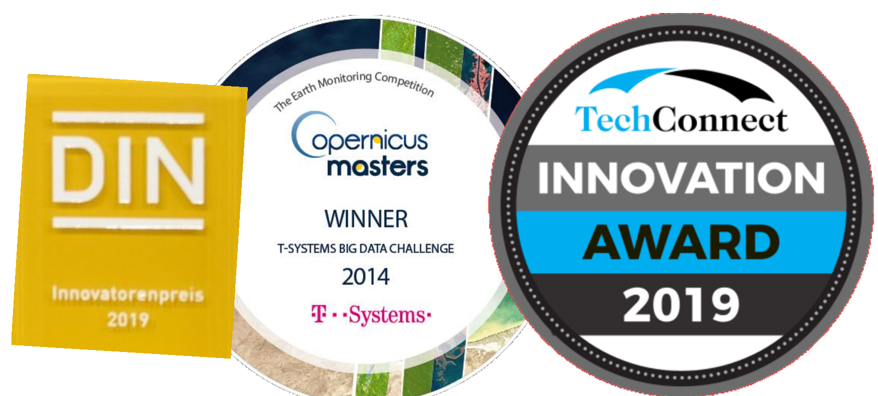


- Ex: rasdaman = Array DBMS
  - Data model: n-D arrays as attributes
  - Query model: Tensor Algebra
  - Demo at http://standards.rasdaman.org

```
select img.raster[x0:x1,y0:y1] > 130
from   LandsatArchive as img
```



- Multi-core, distributed, platform for EarthServer (https://earthserver.xyz)
- Relational? „Array DBMSs can be 200x RDBMS“ [Cudre-Maroux]



Transactions

No More ACID

- RDBMS provide ACID…locally
- Close to impossible to achieve in distributed situations
- Instead: BASE
  - Basically Available Soft-state Eventual Consistency
  - Prefers availability over consistency
- Ex: Cassandra

Outlook: ACID vs BASE

- BASE = Basically Available Soft-state Eventual Consistency
  - availability over consistency, relaxing ACID
  - ACID model promotes consistency over availability,
    BASE promotes availability over consistency
- Comparison:
  - Traditional RDBMSs: Strong consistency over availability under a partition
  - Cassandra: Eventual (weak) consistency, availability, partition-tolerance
- CAP Theorem [proposed: Eric Brewer; proven: Gilbert & Lynch]:
  In a distributed system you can satisfy at most 2 out of the 3 guarantees
  - Consistency: all nodes have same data at any time
  - Availability: system allows operations all the time
  - Partition-tolerance: system continues to work in spite of network partitions

Discussion: ACID vs BASE

- Justin Sheely: “eventual consistency in well-designed systems does not lead to inconsistency”
- Daniel Abadi: “If your database only guarantees eventual consistency, you have to make sure your application is well-designed to resolve all consistency conflicts. […] Application code has to be smart enough to deal with any possible kind of conflict, and resolve them correctly”
  - Sometimes simple policies like “last update wins” sufficient
  - other apps far more complicated, can lead to errors and security flaws
  - Ex: ATM heist with 60s window
  - DB with stronger guarantees greatly simplifies application design

CAP Theorem

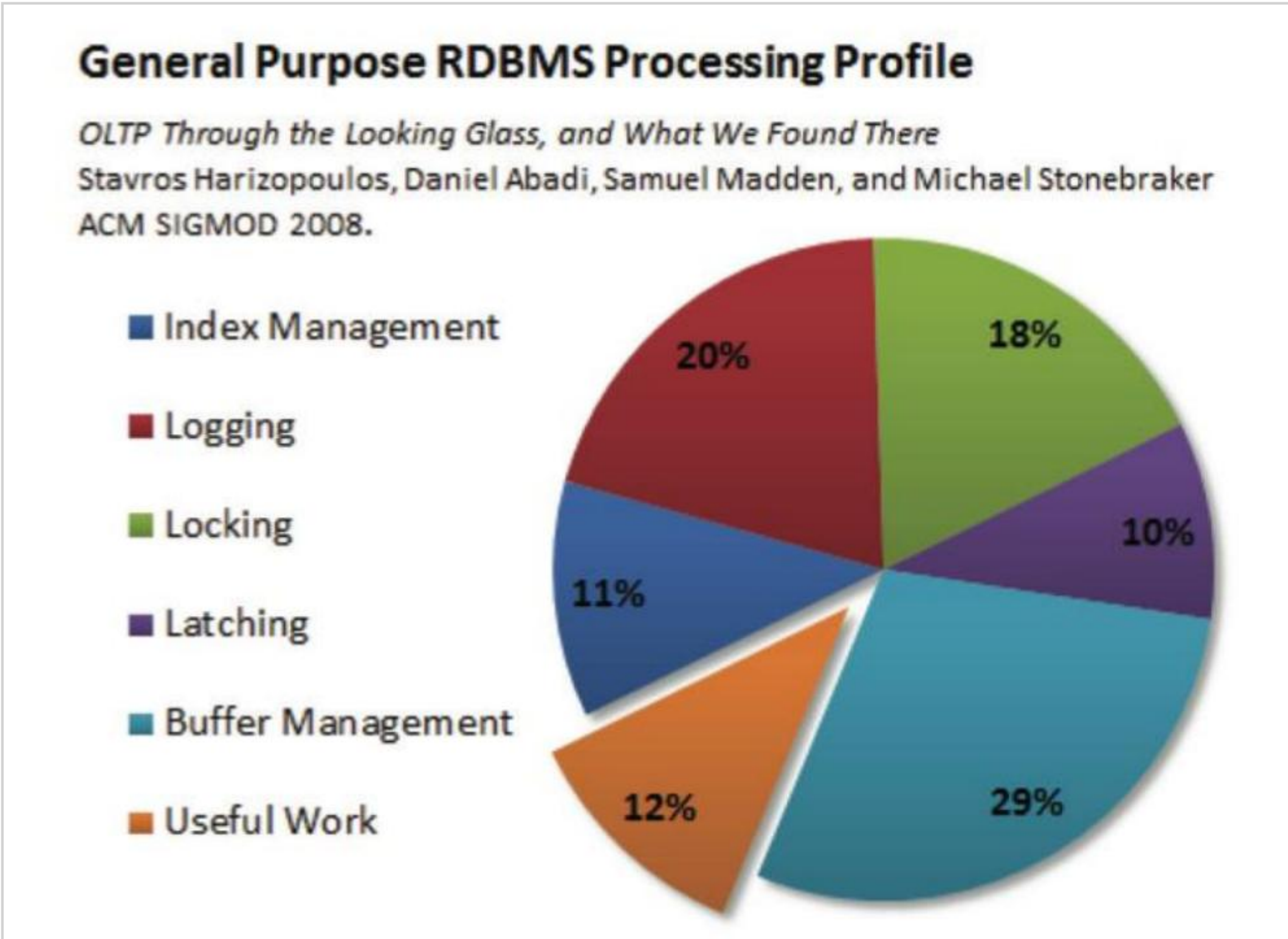
- Proposed by Eric Brewer, UCB; subsequently proved by Gilbert & Lynch
- In a distributed system you can satisfy at most 2 out of the 3 guarantees
  - Consistency: all nodes have same data at any time
  - Availability: system allows operations all the time
  - Partition-tolerance: system continues to work in spite of network partitions
- Traditional RDBMSs
  - Strong consistency over availability under a partition
- Cassandra
  - Eventual (weak) consistency, Availability, Partition-tolerance

NewSQL

NewSQL: *The Empire Strikes Back*

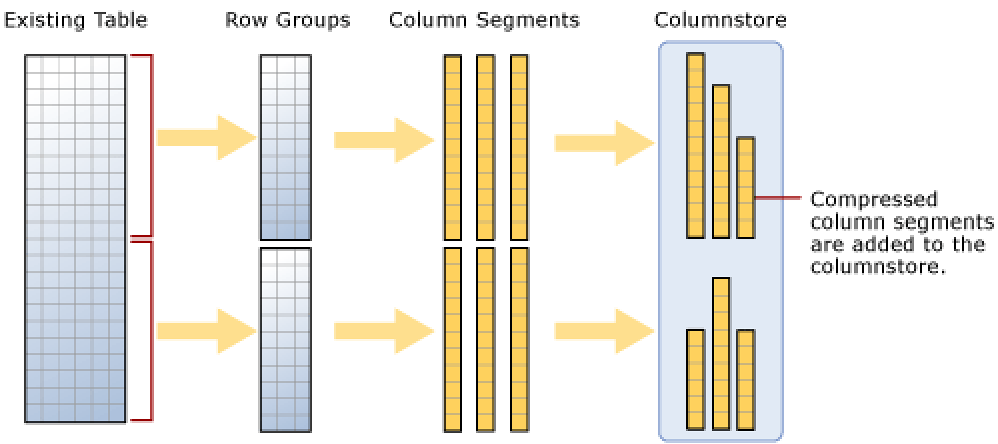
- Michael Stonebraker: „*no one size fits all*"
- NoSQL: sacrificing functionality for performance – no QL, only key access
  - Single round trip fast, complex real-world problems slow
- Swinging back from NoSQL:
  declarative QLs considered good (again), but SQL often inadequate
- Definition 1: NewSQL = SQL with enhanced performance architectures
- Definition 2: NewSQL = SQL enhanced with, eg, new data types
  - Some call this NoSQL

What Makes an RDBMS Slow?



Column-Store Databases

- Observation: fetching long tuples overhead when few attributes needed
- Brute-force decomposition: one value (plus key)
  - Ex: Id+SNLRH → Id+S, Id+N, Id+L, Id+R, Id+H
  - Column-oriented storage:
    each binary table separate file



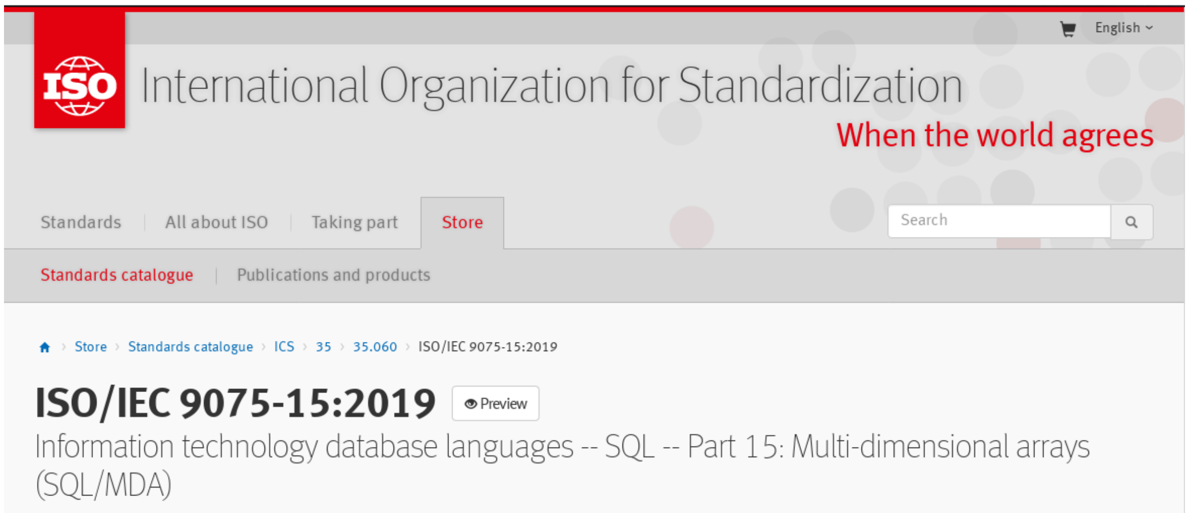
[https://docs.microsoft.com]

- With clever architecture, reassembly of tuples pays off
  - system keys, contiguous, not materialized, compression, MMIO, ...
- Sample systems: MonetDB, Vertica, SAP HANA

Main-Memory Databases

- RAM faster than disk → load data into RAM, process there
  - CPU, GPU, ...
- Largely giving up ACID‘s Durability → different approaches
- Sample systems: ArangoDB, HSQLDB, MonetDB, SAP HANA, VoltDB, ...

Arrays in SQL



- 2014 - 2018
- rasdaman as blueprint

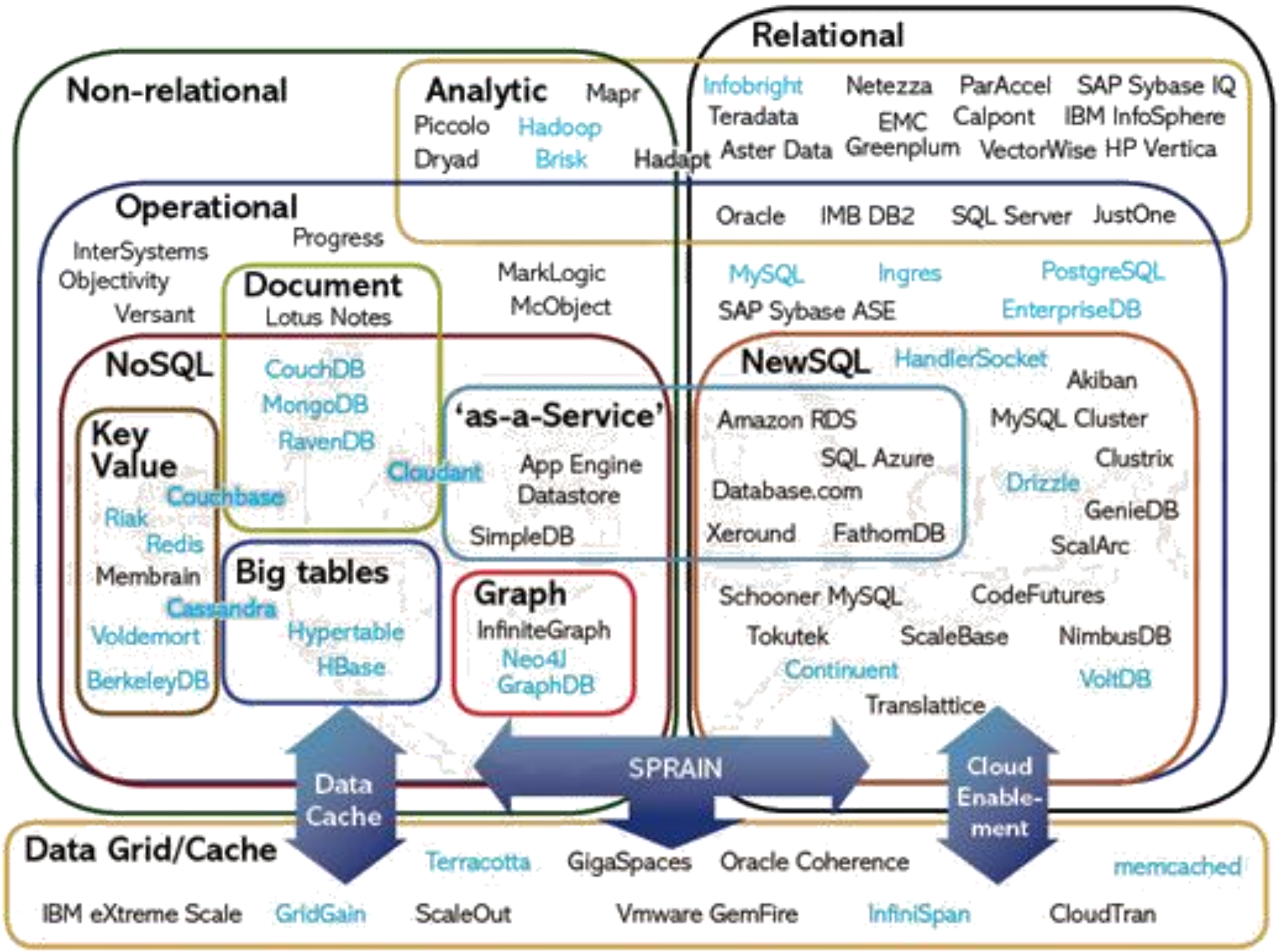
```
create table LandsatScenes(
    id: integer not null, acquired: date,
    scene: row( band1: integer, ..., band7: integer ) mdarray [ 0:4999,0:4999] )
```

```
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
```

Summary & Outlook

- Fresh approach to scalable data services: NoSQL, NewSQL
  - Diversity of technology → pick best of breed for specific problem
- Avenue 1: Modular data frameworks to coexist
  - Heterogeneous model coupling barely understood - needs research
- Avenue 2: concepts assimilated by relational vendors
  - Like fulltext, object-oriented, SPARQL, ... cf „Oracle NoSQL"
- "SQL-as-a-service"
  - Amazon RDS, Microsoft SQL Azure, Google Cloud SQL
- *More than ever, experts in data management needed !*
  - *Both IT engineers and data engineers*

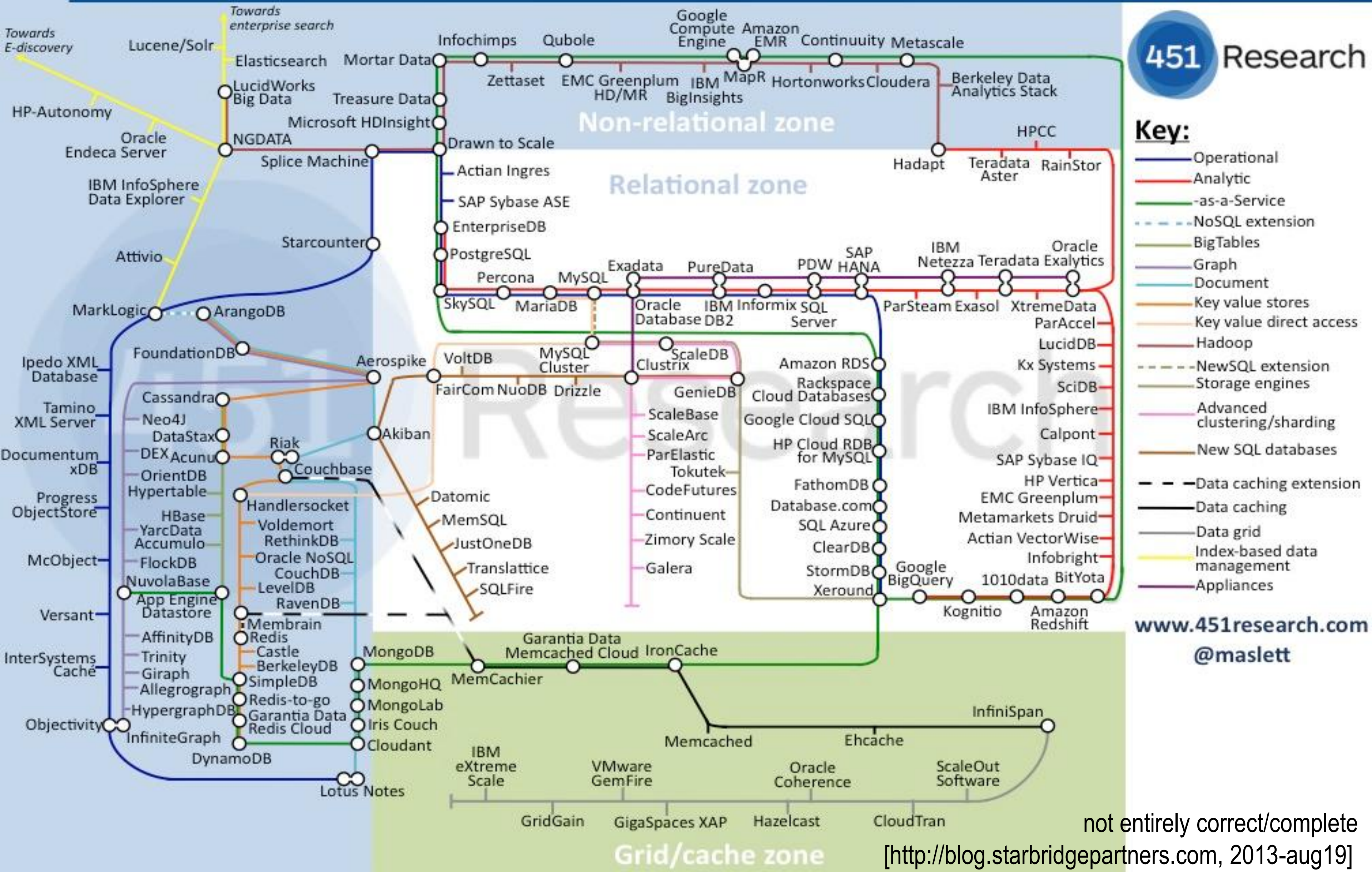
The Explosion of DBMSs



[451 group]

...not entirely correct

Database Landscape Map – December 2012



not entirely correct/complete
[http://blog.starbridgepartners.com, 2013-aug19]