Databases 101

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Slides liberally borrowed and customized from lots of excellent online sources

What we’ll cover today

- Intro to Databases
- Types of Databases
  - Features
  - Pros and Cons
- Working with databases
  - Getting data in
  - Analysis/Querying - SQL
  - Getting data out

Why do we need Databases?

- Store data
- Organize data
- Use data efficiently

History of Databases

- Punch Cards
- Flat Files
- Relational
- NoSQL

Relational Databases

- Represent relations
- Traditionally motivated by the need for transaction processing and analysis
- Use SQL for querying
- Typically normalized but more and more denormalized for analytical reasons

SQL Database Examples

- Commercial
  - Microsoft SQL Server
  - Oracle
  - IBM DB2
  - Teradata
  - Sybase SQL Anywhere
  - …
- Open Source (with commercial options)
  - Sqlite
  - MySQL
  - Postgres
  - Ingres

Transactions – ACID Properties

- **A**tomic – All of the work in a transaction completes (commit) or none of it completes
- **C**onsistent – A transaction transforms the database from one consistent state to another consistent state. Consistency is defined in terms of constraints.
- **I**solated – The results of any changes made during a transaction are not visible until the transaction has committed.
- **D**urable – The results of a committed transaction survive failures

Why NoSQL?

- Initially motivated by web applications
- Hack was to front a relational DB with a cache for reading and writing
- Scaling Issues
  - Master slave is slow and expensive
  - Sharding is not ubiquitous and joins don't work

What is NoSQL?

- Stands for **N**ot **O**nly **SQL** or **Not** SQL (people argue about this all the time)
- Class of non-relational data storage systems
- "Usually" do not require a fixed table schema nor do they use the concept of joins
- **All NoSQL dbs relax one or more of the ACID properties (CAP theorem)**

CAP Theorem

- Three properties of a system: consistency, availability and partitions

- You can have at most two of these three properties for any shared-data system

- To scale out, you have to partition. That leaves either consistency or availability to choose from
  - In almost all cases, you would choose availability over consistency

Availability

- Traditionally, thought of as the server/process available five 9’s (99.999 %).

- However, for large node system, at almost any point in time there’s a good chance that a node is either down or there is a network disruption among the nodes.
  - Want a system that is resilient in the face of network disruption

Consistency Model

- A consistency model determines rules for visibility and apparent order of updates.
- For example:
  - Row X is replicated on nodes M and N
  - Client A writes row X to node N
  - Some period of time t elapses.
  - Client B reads row X from node M
  - Does client B see the write from client A?
  - Consistency is a continuum with tradeoffs
  - For NoSQL, the answer would be: maybe
  - CAP Theorem states: Strict Consistency can't be achieved at the same time as availability and partition-tolerance.

Eventual Consistency

- When no updates occur for a long period of time, eventually all updates will propagate through the system and all the nodes will be consistent

- For a given accepted update and a given node, eventually either the update reaches the node or the node is removed from service

- Known as BASE (**B**asically **A**vailable, **S**oft state, **E**ventual consistency), as opposed to ACID

When to NoSQL

- Unknown/flexible schema
- Bursty usage (easy scaling)
- Simplish queries
- Fast read access

NoSQL Database Types

- Key-Value Pair
- Document Database
- Column Database
- Graph Database

What kinds of NoSQL

- Key/Value Stores or ‘the big hash table’.
  – Amazon S3 (Dynamo)
  – Voldemort
  – Scalaris

- Schema-less which comes in multiple flavors, column-based, document-based or graph-based.
  – Cassandra (column-based)
  – CouchDB (document-based)
  – Neo4J (graph-based)
  – HBase (column-based)

Key/Value

Pros:

– very fast

– very scalable

– simple model

– able to distribute horizontally

Cons:

- many data structures (objects) can't be easily modeled as key value pairs

Key-Value Stores

- Memcached – Key value stores.
- Membase – Memcached with persistence and improved consistent hashing.
- AppFabric Cache – Multi region Cache.
- Redis – Data structure server.
- Riak – Based on Amazon's Dynamo.
- Project Voldemort – eventual consistent key value stores, auto scaling.

Beyond Key-Values but Schema-Less

Pros:

- Schema-less data model is richer than key/value pairs
- eventual consistency
- many are distributed
- still provide excellent performance and scalability

Cons:

- typically no ACID transactions or joins

Document Stores

- Schema Free.
- Usually JSON like interchange model.
- Query Model: JavaScript or custom.
- Aggregations: Map/Reduce.
- Indexes are done via B-Trees.

Document Store Examples

- Example: CouchDB
  - http://couchdb.apache.org/
  - BBC
- Example: MongoDB
  - http://www.mongodb.org/
  - Foursquare, Shutterfly
- Store as JSON (JavaScript Object Notation)

CouchDB JSON Example


```
{
  "_id": "guid goes here",
  "_rev": "314159",

  "type": "abstract",

  "author": "Keith W. Hare"

  "title": "SQL Standard and NoSQL Databases",

  "body": "NoSQL databases (either no-SQL or Not Only SQL)
           are currently a hot topic in some parts of
           computing.",
  "creation_timestamp": "2011/05/10 13:30:00 +0004"
}
```

Column Store

- Each storage block contains data from only one column
- Example: Hadoop/Hbase
  - http://hadoop.apache.org/
  - Yahoo, Facebook
- Examples: Vertica, Ingres VectorWise
  - Column Store integrated with an SQL database

Column Stores

- More efficient than row (or document) store if:
  - Multiple row/record/documents are inserted at the same time so updates of column blocks can be aggregated
  - Retrievals access only some of the columns in a row/record/document

Graph Stores

- Useful for storing triples (nodes and edges)
- Scale vertically, no clustering.
- You can use graph algorithms easily.
- Neo4J, OrientDB, FlockDB

NoSQL - Common Advantages

- Cheap, easy to implement (open source)
- Data are replicated to multiple nodes (therefore identical and fault-tolerant) and can be partitioned
  - Down nodes easily replaced
  - No single point of failure
- Easy to distribute
- Don't require a schema
- Can scale up and down
- Relax the data consistency requirement (CAP)

What am I giving up?

- Joins (mostly)
- group by
- order by
- ACID transactions
- SQL
- Easy integration with other applications that support SQL

Typical NoSQL API

- Basic API access:
  - get(key) -- Extract the value given a key
  - put(key, value) -- Create or update the value given its key
  - delete(key) -- Remove the key and its associated value
  - execute(key, operation, parameters) -- Invoke an operation to the value (given its key) which is a special data structure (e.g. List, Set, Map .... etc).

Searching

- Relational
  - SELECT \`column\` FROM \`database\`,\`table\` WHERE \`id\` = key;
  - SELECT product_name FROM rockets WHERE id = 123;
- Cassandra (standard)
  - keyspace.getSlice(key, “column_family”, "column")
  - keyspace.getSlice(123, **new** ColumnParent(“rockets”), *getSlicePredicate*());

Some Statistics

- Facebook Search
- MySQL > 50 GB Data
  - Writes Average : ~300 ms
  - Reads Average : ~350 ms
- Rewritten with Cassandra > 50 GB Data
  - Writes Average : 0.12 ms
  - Reads Average : 15 ms

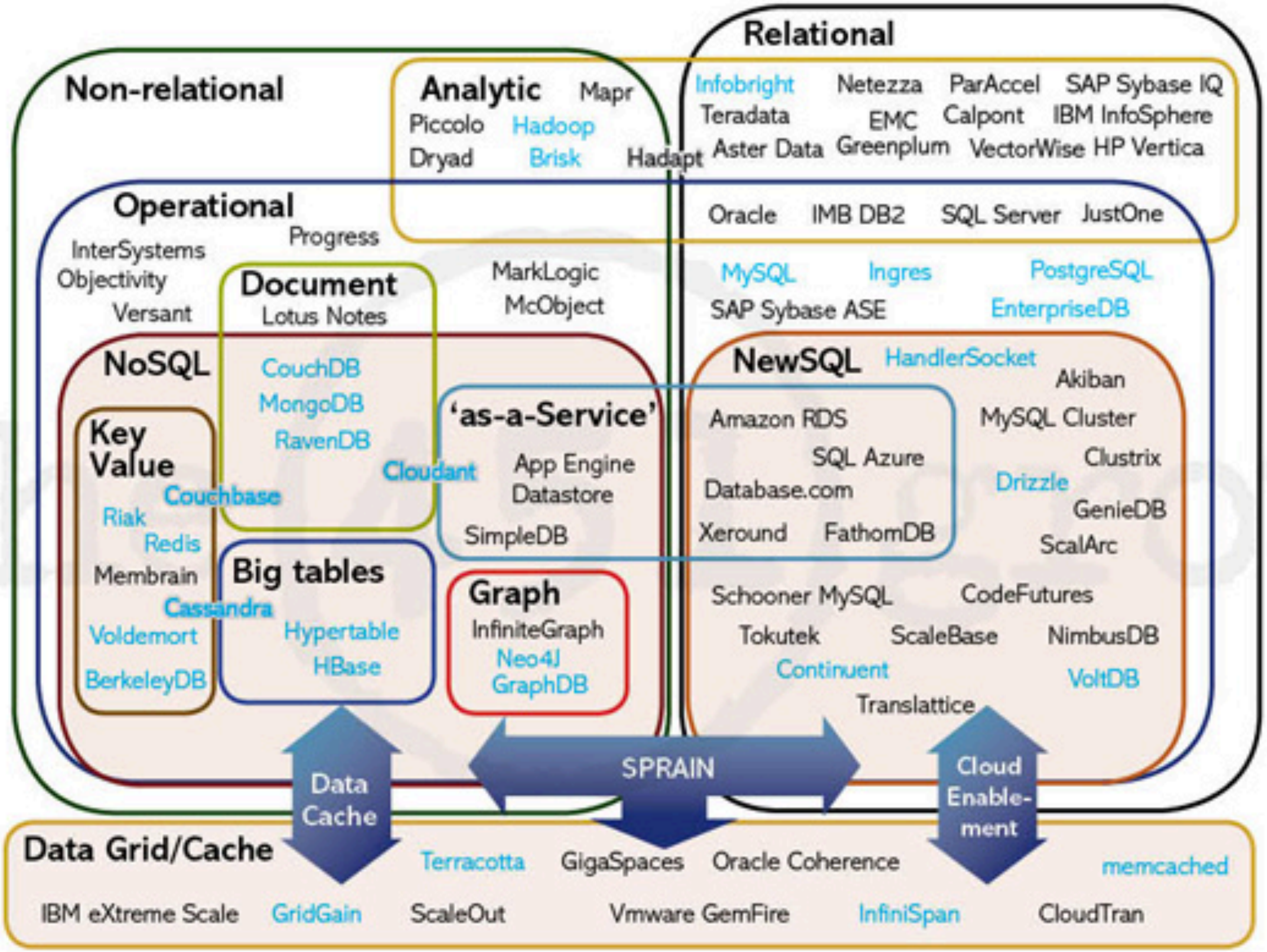
Where would I use them?

- Log Analysis
- Social Networking Feeds (many firms hooked in through Facebook or Twitter)
- Data that is not easily analyzed in a RDBMS such as time-based data
- Large data feeds that need to be massaged before entry into an RDBMS

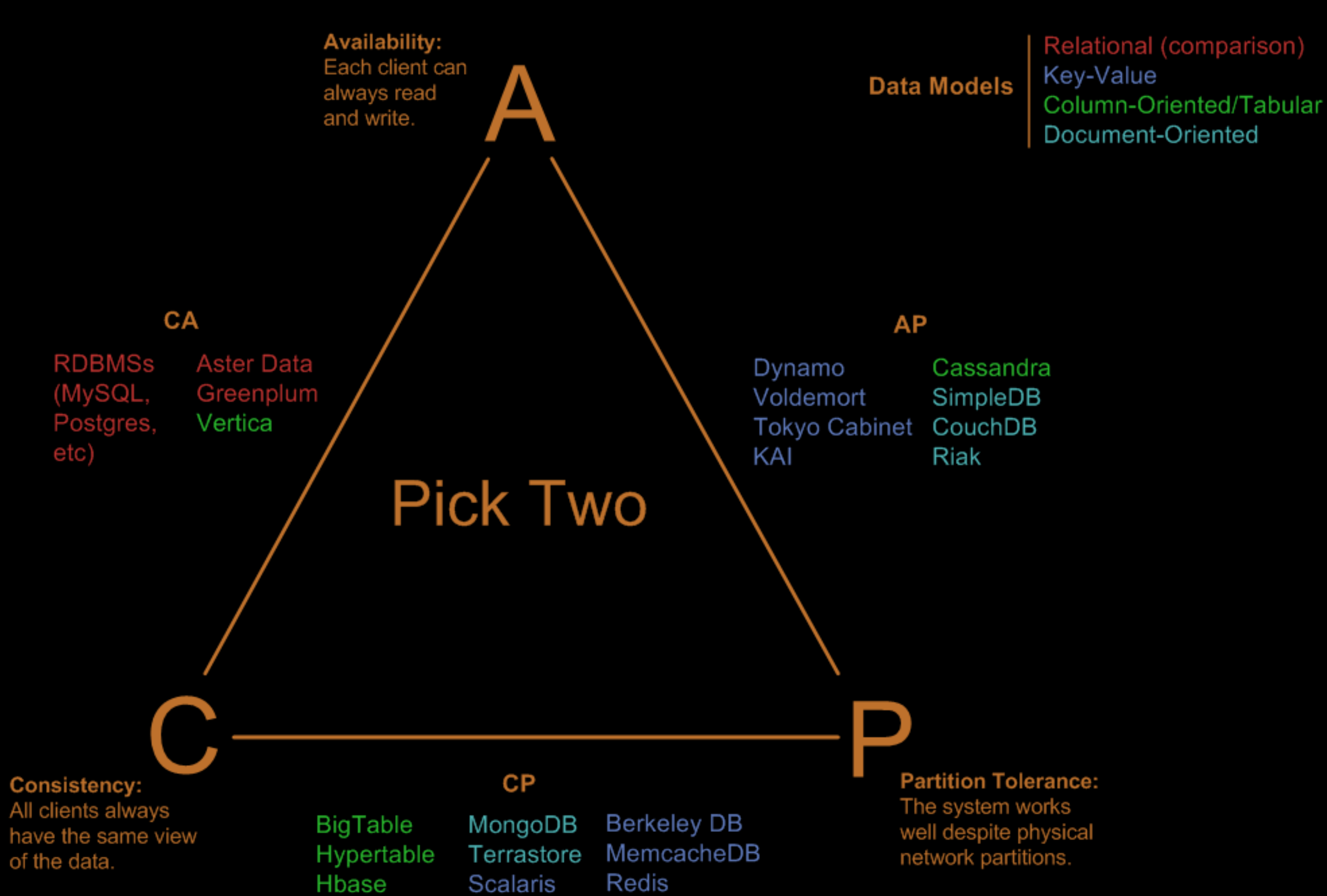
NoSQL Distinguishing Characteristics

- Large data volumes
- Scalable replication and distribution
  - Potentially thousands of machines
  - Potentially distributed around the world
- Queries need to return answers quickly
- Mostly query, few updates
- Asynchronous Inserts & Updates
- Schema-less
- ACID transaction properties are not needed – BASE

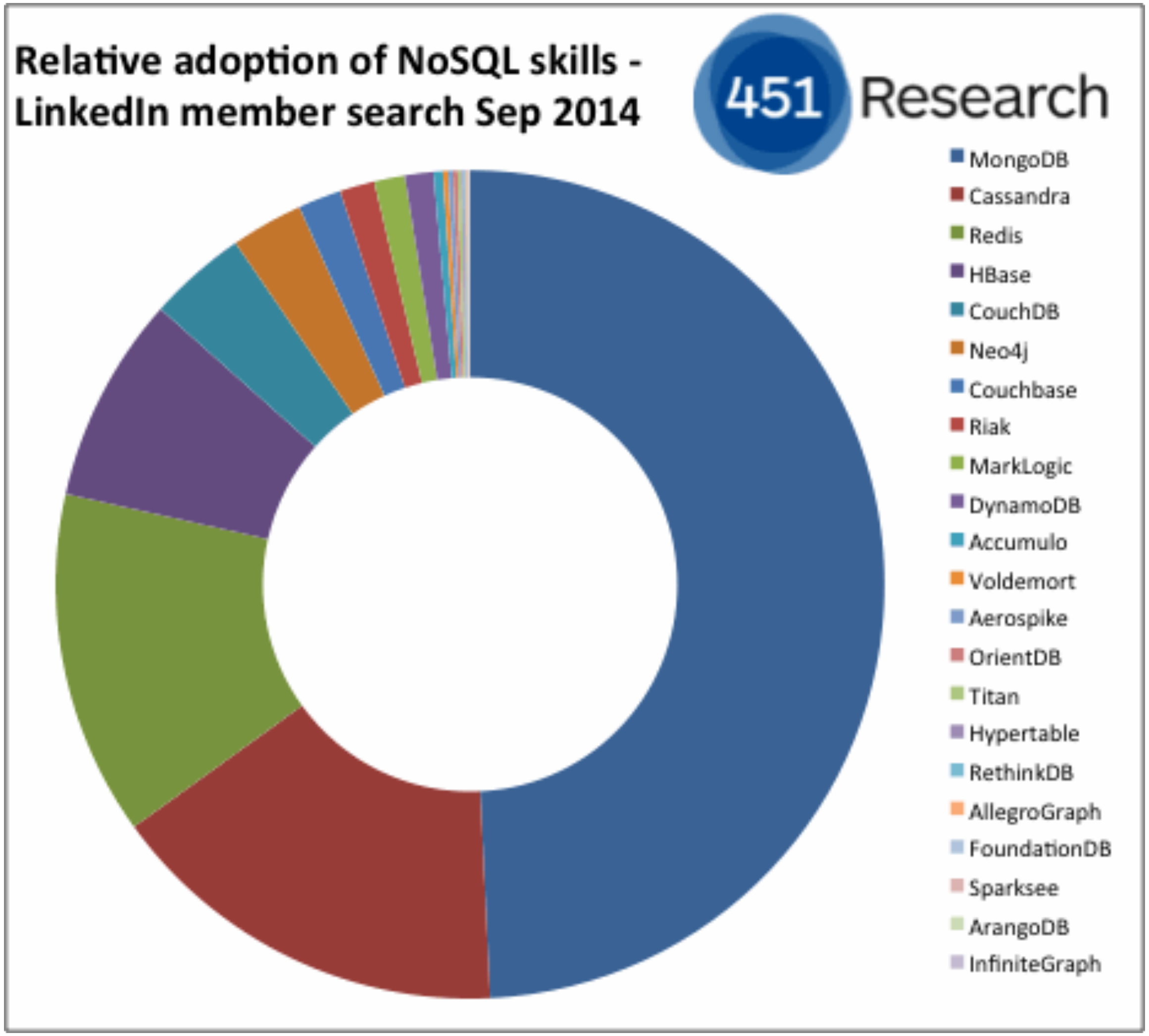
Database Map



Visual Guide to NoSQL Systems



Popularity



Relative adoption of NoSQL skills - LinkedIn member search Sep 2014
451 Research
MongoDB
Cassandra
Redis
HBase
CouchDB
Neo4j
Couchbase
Riak
MarkLogic
DynamoDB
Accumulo
Voldemort
Aerospike
OrientDB
Titan
Hypertable
RethinkDB
AllegroGraph
FoundationDB
Sparksee
ArangoDB
InfiniteGraph

Intro to SQL

Data Import and Export for MySQL

- Import
  - LOAD DATA INFILE ‘filename’ INTO TABLE tablename;
  - Mysqlimport

- Export
  - SELECT * FROM tablename INTO OUTFILE ‘filename’;

SQL

- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
  - Following lectures...

- Data Manipulation Language (DML)
  - Query one or more tables – discussed next !
  - Insert/delete/modify tuples in tables

Data Types in SQL

- Atomic types:
  - Characters: CHAR(20), VARCHAR(50)
  - Numbers: INT, BIGINT, SMALLINT, FLOAT
  - Others: MONEY, DATETIME, …

- Every attribute must have an atomic type

SQL Query – Basic form

```
SELECT  <attributes>
FROM    <one or more relations>
WHERE   <conditions>
```

Operators

- Like
- Distinct
- Order by
- Group by
- Aggregation
- Joins

Aggregation

```
SELECT    S
FROM      R_1,…,R_n
WHERE     C1
GROUP BY  a_1,…,a_k
HAVING    C2
```

Evaluation steps:

1. Evaluate FROM-WHERE, apply condition C1
2. Group by the attributes $a_1,\ldots,a_k$
3. Apply condition C2 to each group (may have aggregates)
4. Compute aggregates in S and return the result

Modifying the Database

- Insertions
  - INSERT INTO R(A1,…., An) VALUES (v1,…., vn)
- Deletions
  - DELETE FROM PURCHASE WHERE seller = 'Joe' AND product = 'Brooklyn Bridge'
- Updates
  - UPDATE PRODUCT SET price = price/2 WHERE

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