NoSQL Databases

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Outline

- What?
- Why?
- NoSQL databases
  - Key-value stores
  - Wide column stores
  - Map reduce
  - more…

What?

- NoSQL != No SQL
- NoSQL an umbrella term for data stores that don't follow RDBMS principles
  - Data may not be relational
  - SQL may or may not be used
  - Schema may not be available
  - BASE consistency model (much loser than ACID)
- NoSQL ~ "not only SQL"

Why?

- We want our access to data to be
  - Convenient
  - Reliable
  - Scalable
  - Efficient

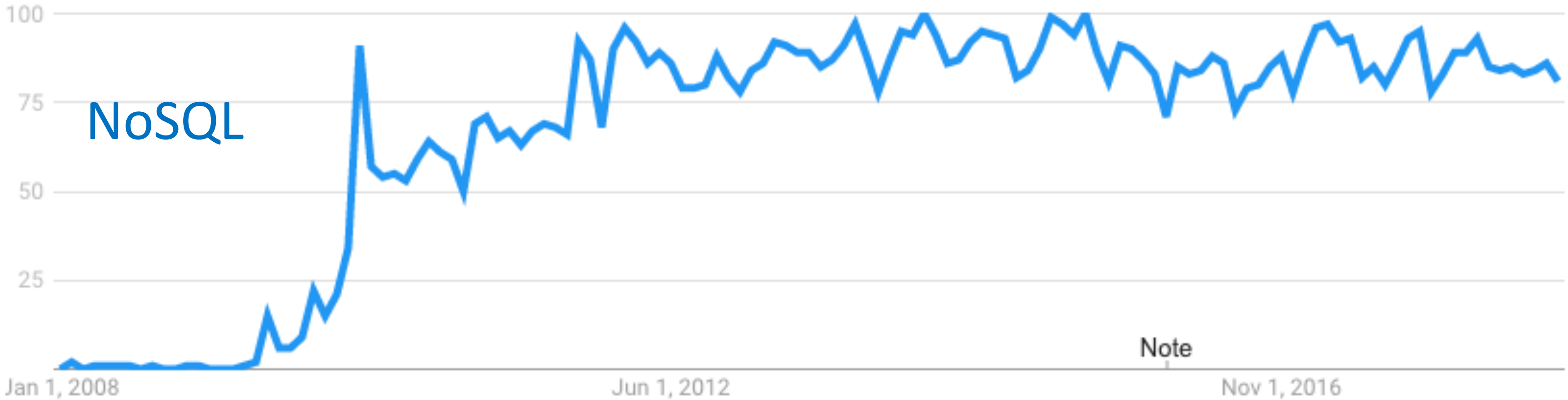
Why?

- We want our access to data to be
  - ~~Convenient~~
  - ~~Reliable~~
  - Scalable
  - Efficient
- Willing to sacrifice convenience and reliability for scalability and efficiency

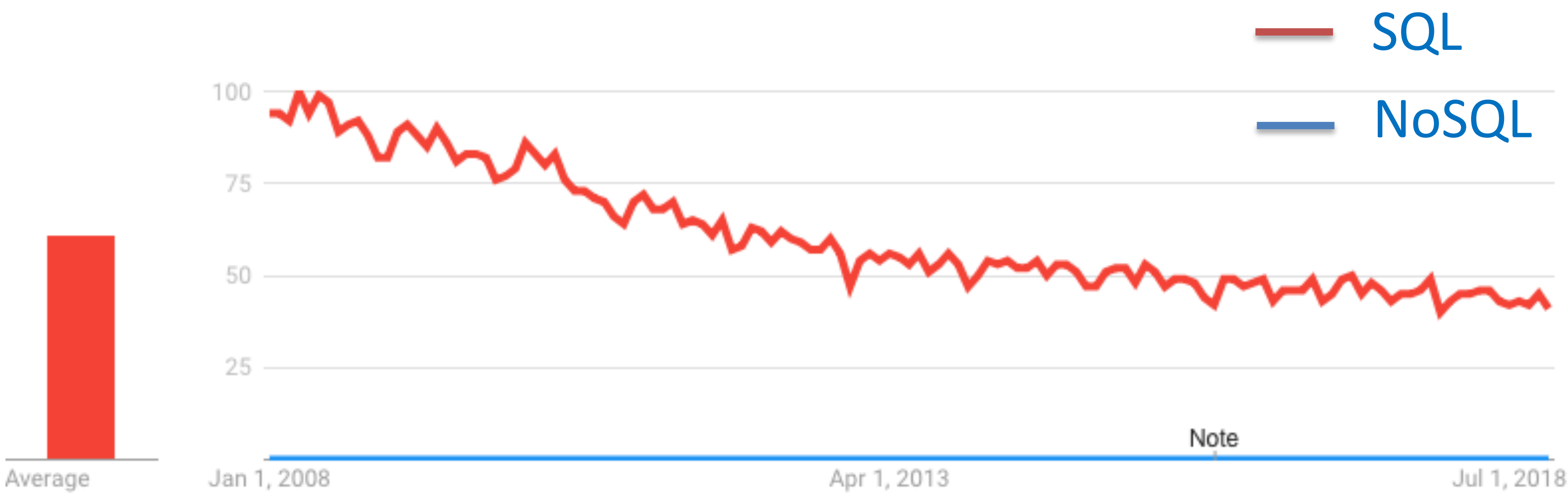
Gaining in popularity …

Google

Trends



… but still behind SQL



NoSQL Systems

- As an alternative to relational DBMS
  - More flexible schema
  - Cheaper to setup
  - Better scalability in some cases
  - Higher performance and availability (with a relaxed consistency)

Positive

  - More programming (less declarative querying)
  - Less consistency

Negative

ACID

- Atomicity
  - Transactions are atomic
- Consistency
  - Database is always moved from one consistent state to another (through transactions)
  - Applications are insulated from dirty reads and writes
- Isolation
  - Transactions can run concurrently
- Durability
  - Committed transactions cannot be lost (e.g. due to power failure)

BASE Consistency Model

- Basic availability
  - Database available most of the time
- Soft state
  - Stores and replicas may not be consistent
- Eventual consistency
  - Stores may not have the latest updates
    - common in distributed systems

Trade consistency for high availability

NoSQL Databases

- Key-value stores
- Wide column stores
- Document stores
- Graph data stores
- Map-reduce
- More…

Key-Value

- Data storage for a binary table (key, value)
  - Aka dictionary, hash or hashmap
- Examples
  - (url, content), (term, docids)
  - (stuid, courses_enrolled), (stuid, contact_Info)
- Relational to key-value mapping
  - (sin,<name,phone>)
  - (sin, name), (sin, phone)

Key-Value Stores

- Simple interface
  - Data model: (key, value) pairs
  - Operations: insert(key, value), update(key, value), fetch(key), delete(key)
- Efficient/scalable implementation
  - Records distributed to machines based on key
  - Fault tolerance is supported by replication
    - Replicas: eventually consistent
  - Single record transactions

Key-Value Stores

- Redis
  - A networked in-memory store
  - Supports lists, sets, hashes, …
  - A set of operations to operate over the supported types
  - Client-server model
  - Open source and quite popular
  - Optional durability with a snapshot stored on disk

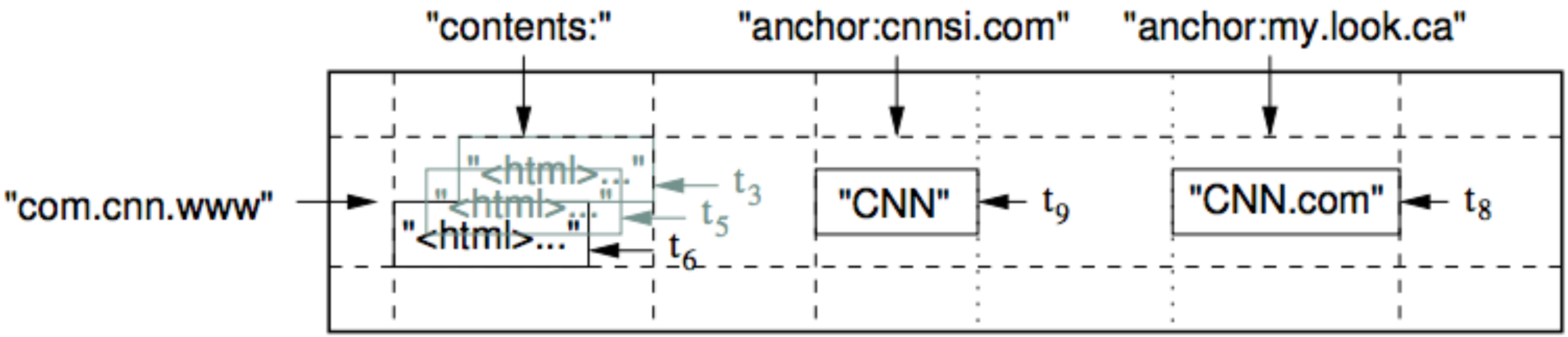
Key-Value Stores (Cont.)

- Berkeley DB
  - A disk-based store
  - Supports btree, hash, queue, recno (heap)
  - No network access (similar to SQLite)
  - Supports transactions

Wide Column Stores

- Data can have too many columns and those columns may change over time
  - E.g. Time series, streaming events
- Columns can change from one row to next
- A limited set of column families (e.g. hobby, jobs) but an infinite number of values in each family
- A timestmap may be assigned to each cell (at a row and a column)

A Use Case for Google Bigtable



Another Use Case

"follows" column family

	Follows			
Row Key	gwashington	jadams	tjefferson	wmckinley
gwashington		1		
jadams	1		1	
tjefferson	1	1		1
wmckinley			1	

Multiple versions

Wide Column Stores

- Data stored as records
- Number and names of columns are not fixed
  - A record can have millions of columns
  - Columns change dynamically
- Seen as two-dimensional key-value stores
- Examples of column stores
  - Google's BigTable
  - Cassandra
  - Hbase
  - Microsoft Azure Cosmos DB

Document Store

- Consider storing the following json document in an RDBMS

```
{
 {title: 'This is a sample post',
  desc: 'document store sample',
  by: 'Joe221',
  url: 'www.a.com/p200.html',
  tags: ['davood', '291', 'database'],
  likes: 40}
,
 {title: 'CMPUT 291',
  desc: 'a course in databases',
  by: 'davood',
  url: 'www.a.com/p202.html',
  tags: ['nosql', 'database', '291', 'example'],
  likes: 38,
  comments: [ {user: 'bob10',
                msg: 'great post',
               post_date: 'Oct 19, 2017',
               like: 2}]}
}
```

RDBMS Tables

- Posts(post_id, title, desc, by, url, likes)
- Tags(tid, post_id, tag)
- Comments(cid, post_id, by, msg, post_date, likes)

Multiple insert statements per document

A document Store

- Insert into store *db* under collection *posts*
  - Db.posts.insert([{title: ….}])
- Find and print it
  - Db.posts.find({“by”: “davood”}).pretty()
  - Db.posts.find({“likes”: {$gt:20}}).pretty()
- Document encoding: json, xml, etc.
- Each document has a (implicit/explicit) key
  - Unlike key-value stores, content can be searched

Document Stores

- ElasticSearch
  - An infrastructure on top of Apache's Lucene
  - Stores json in a distributed fashion
  - Scales well across machines and data centers
  - Support searches over documents
  - Each document is stored under a url
    - https://localhost:9200/index-name/type-name/id

ElasticSearch

CRUD operations

curl -XPUT "http://localhost:9200/movies/movie/1" -d'
{
    "title": "It is a wonderful life",
    "director": "Frank Capra",
    "year": 1946,
    "genre": ["drama","family"]
}'

Store in index movies

curl -XGET "http://localhost:9200/movies/movie/1" -d'

Access by id

curl -XPOST "http://localhost:9200/_search" -d'
{
    "query": {
        "query_string":{"query":"life"}
    }
}'

Free text search

curl -XPOST "http://localhost:9200/_search" -d'
{
    "query": {
        "query_string":{"query":"life", "fields":["title"]}
    }
}'

Search in title

curl -CDELETE "http://localhost:9200/movies/movie/1" -d''

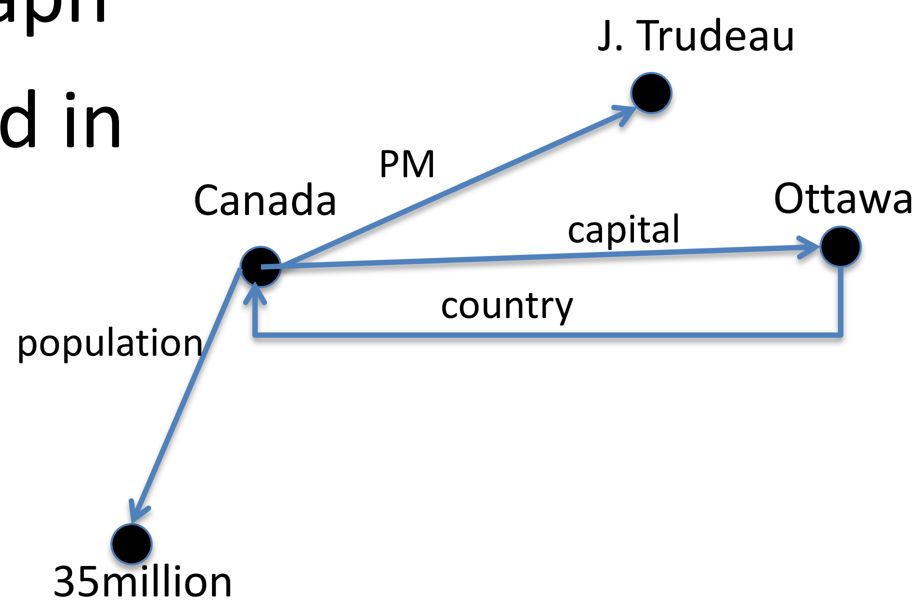
Delete it

Other Document Stores

- MongoDB (covered in our labs and Project 2)
- CouchDB
- Azure DocumentDB
- Many more…

Graph Databases

- Let nodes represent entities and edges describe relationships.
- e.g. knowledge graph
- Data may be stored in a Rel. DB



Triple Stores

- Set of triples (subject, predicate, object)
  - E.g. (Canada, capital, Ottawa), (Canada, prime_minister, J_Trudu)
- Queried using graph patterns

SPARQL

- Datasets
  - Dbpedia

<http://dbpedia.org/resource/Camrose,_Alberta> <http://xmlns.com/foaf/0.1/name> "City of Camrose” .
<http://dbpedia.org/resource/Banff,_Alberta> <http://xmlns.com/foaf/0.1/name> "Town of Banff” .
<http://dbpedia.org/resource/Camrose,_Alberta> <http://dbpedia.org/ontology/populationTotal> ”19742” .
<http://dbpedia.org/resource/James_Gosling> <http://dbpedia.org/ontology/birthPlace> <http://dbpedia.org/resource/Alberta> .
<http://dbpedia.org/resource/Java_programming_language> <http://dbpedia.org/ontology/developer> <http://dbpedia.org/resource/James_G
<http://dbpedia.org/resource/James_Gosling> <http://dbpedia.org/ontology/award> <http://dbpedia.org/resource/Order_of_Canada> .
<http://dbpedia.org/resource/James_Gosling> <http://dbpedia.org/ontology/employer> <http://dbpedia.org/resource/Google> .

  - Our own data

@prefix foaf: <http://xmlns.com/foaf/0.1> .
@prefix uofa: <http://www.ualberta.ca/ontology> .

<http://www.ualberta.ca/people/davood> foaf:name “Davood Rafiei” .
<http://www.ualberta.ca/courses/291> foaf:name “File and Data Management” .
<http://www.ualberta.ca/people/davood> uofa:teach <http://www.ualberta.ca/courses/291> .

SPARQL

- Queries

```
@prefix foaf: <http://xmlns.com/foaf/0.1> .
@prefix uofa: <http://www.ualberta.ca/ontology> .
@prefix dbr: <http://dbpedia.org/resource> .
@prefix dbo: <http://dbpedia.org/ontology> .


SELECT ?name
WHERE {
        ?person  foaf:name  ?name  .
}

SELECT ?person
WHERE {
        dbr:Java_programming_language   dbo:developer  ?person  .
}
```

SPARQL

- Queries

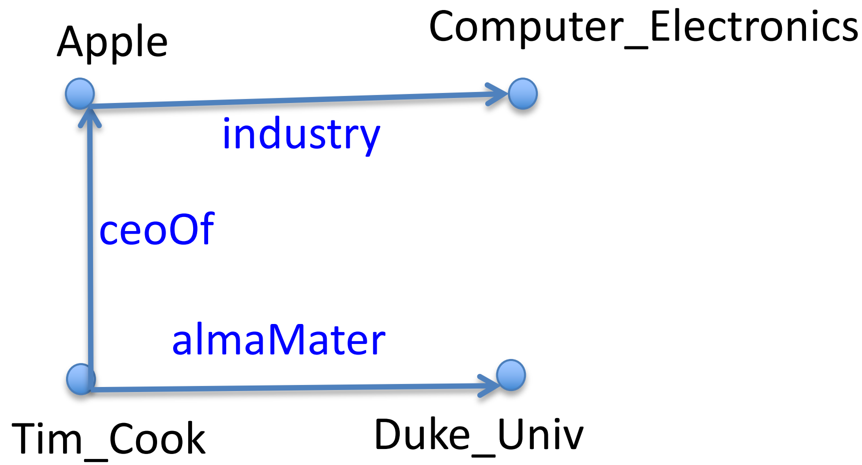
```
@prefix foaf: <http://xmlns.com/foaf/0.1> .
@prefix uofa: <http://www.ualberta.ca/ontology> .
@prefix dbr: <http://dbpedia.org/resource> .
@prefix dbo: <http://dbpedia.org/ontology> .


SELECT ?invention
WHERE {
        ?invention   dbo:developer   ?person .
        ?person  dbo:birthPlace  <http://dbpedia.org/resource/Alberta> .
}
```

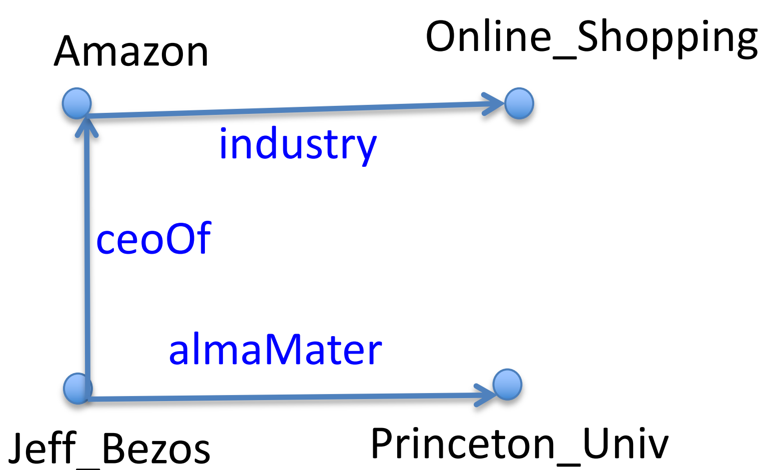
Query By Example

Apple Computer_Electronics

Tim_Cook Duke_Univ.



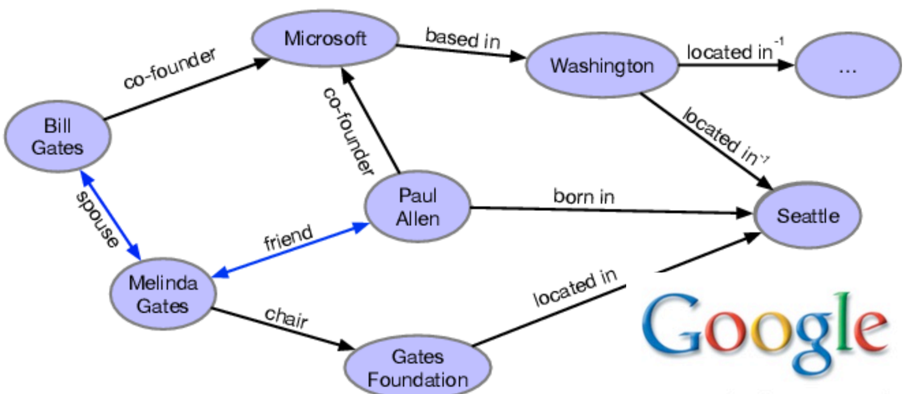
Output:



Shao, Rafiei, Palpanas, 2017

Knowledge Graphs

- Heterogenous graphs
  - With multiple relation types
- Represent facts as triples



Google Knowledge Graph

Microsoft Satori

NELL: Never-Ending Language Learning

Freebase

DBpedia

YAGO

OpenIE (Reverb, OLLIE)

Applications

- Recommendations
  - Suggest relevant items
- Question answering
- Search engines
- Drug repurposing

Freebase

- ~80 million entities
- ~38k relation types
- ~3 billion facts/triples
- Many missing relationships
  - E.g. 93.8% of persons in freebase have no place of birth and 78.5% have no nationality
- Questions
  - How to query an incomplete graph?
  - How to reason about missing edges?

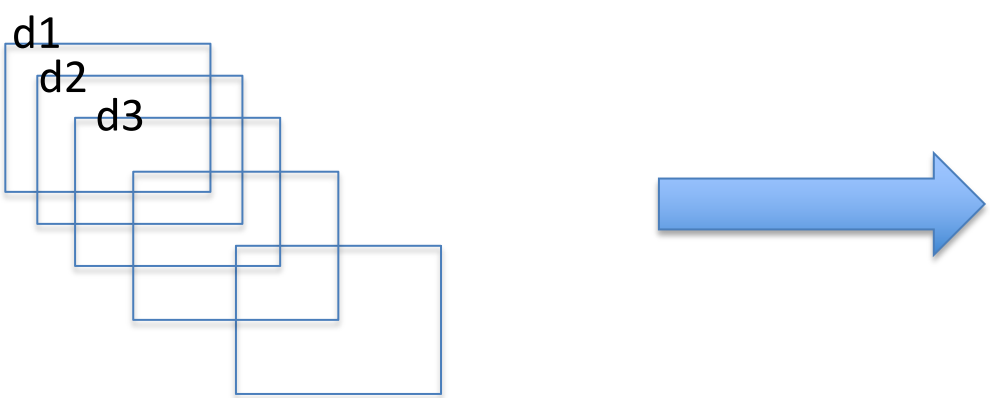
Map Reduce

- Developed at Google in 2004
- Problem:
  - Data files are spread over 1000's of machines
  - How to collect information quickly?
- Parallelism
  - Take advantage of the data spread

Hadoop: open source implementation of MapReduce

Map Reduce

- Large scale data processing over a network of machines
  - More machines leads to more parallelism and less response time
- Data stored in files
- E.g. computing word counts

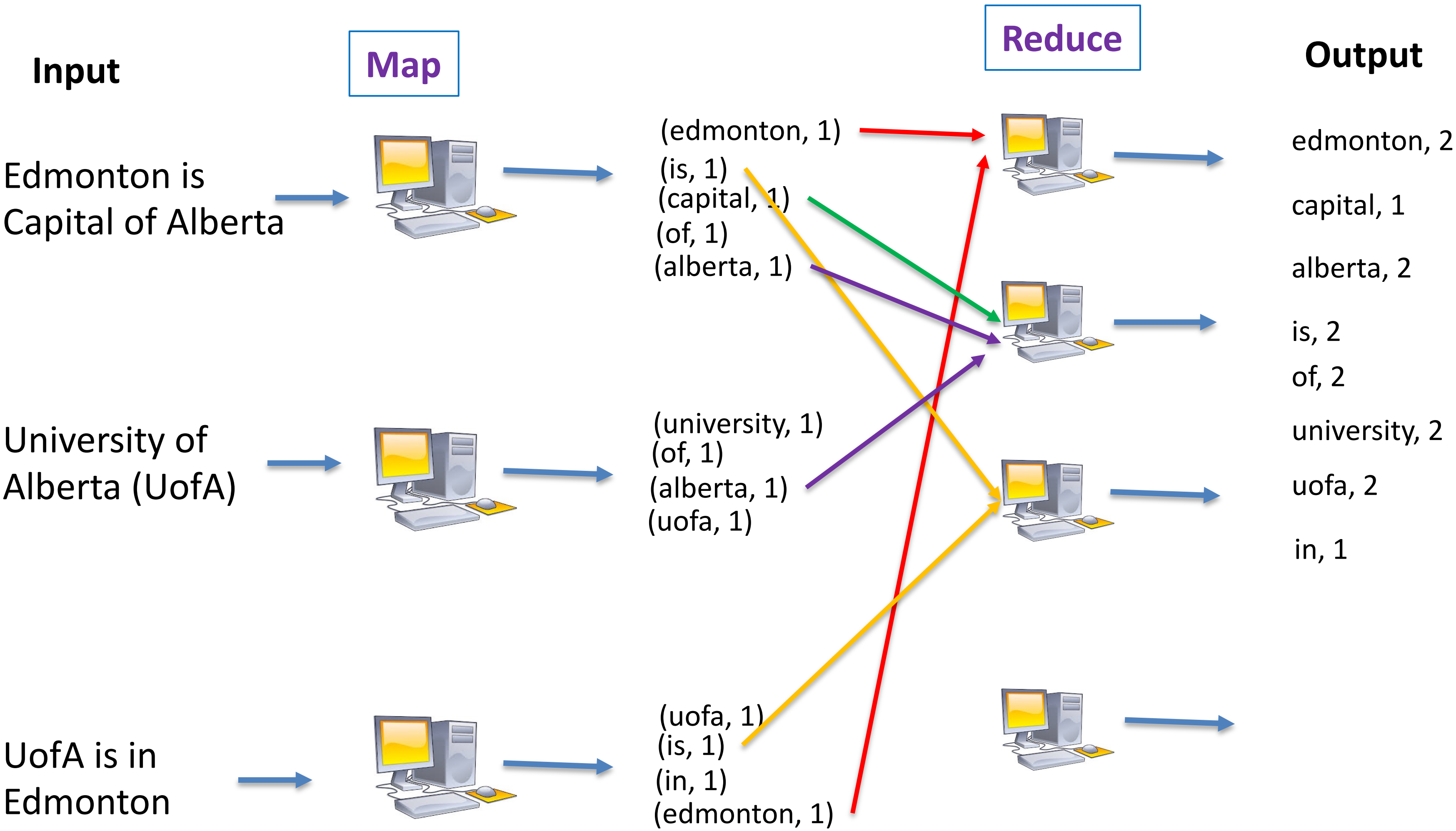


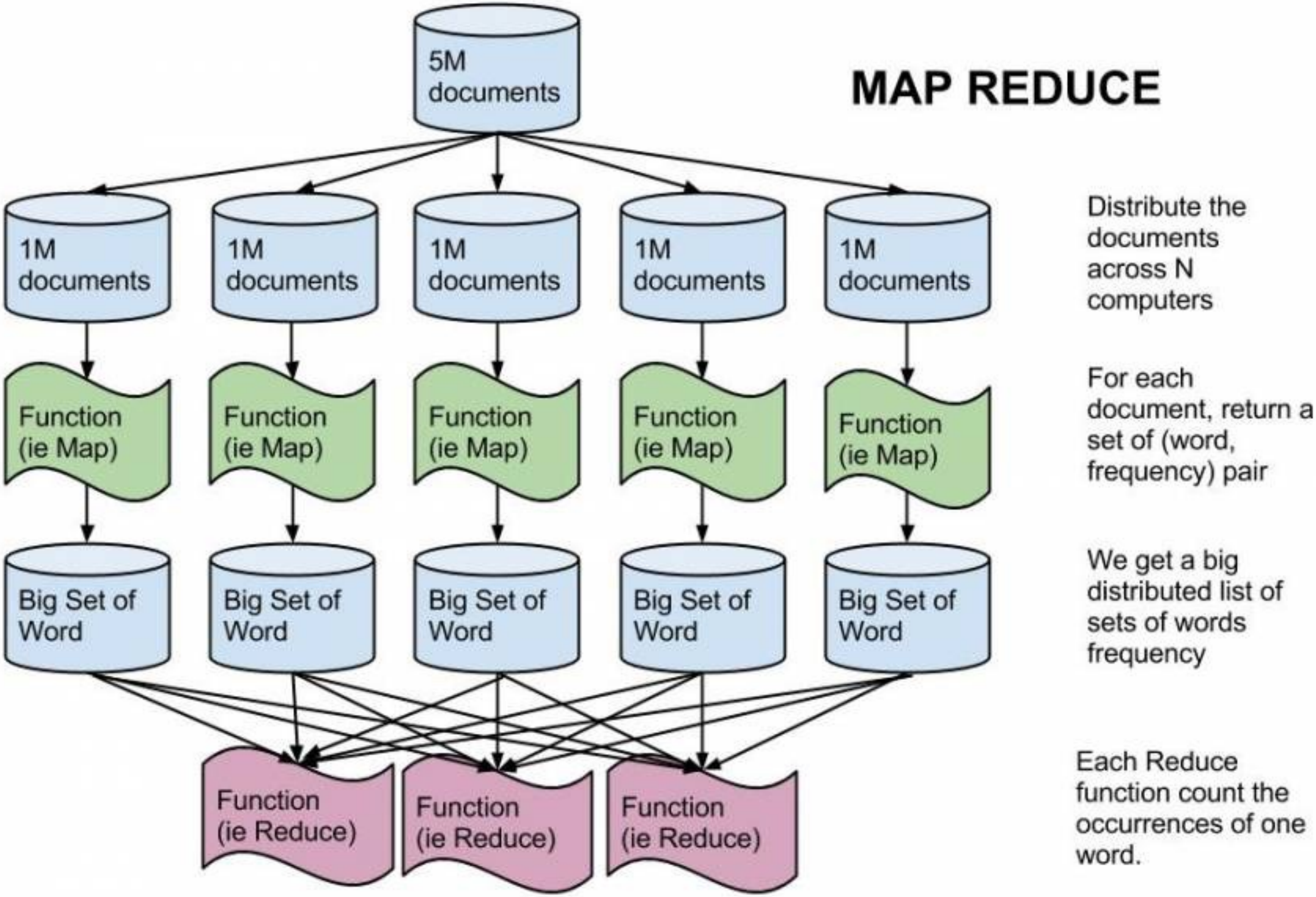
(term, number_of_docs)
(database, 1250)
(relational,600)
…

Two Functions

- Map: divide the problem into smaller problems
  - Map(d1) → (key, value) pairs
- Reduce: work on sub-problems and combine the results
  - reduce(key, set of values) → (key, summary)

Word Counts Example



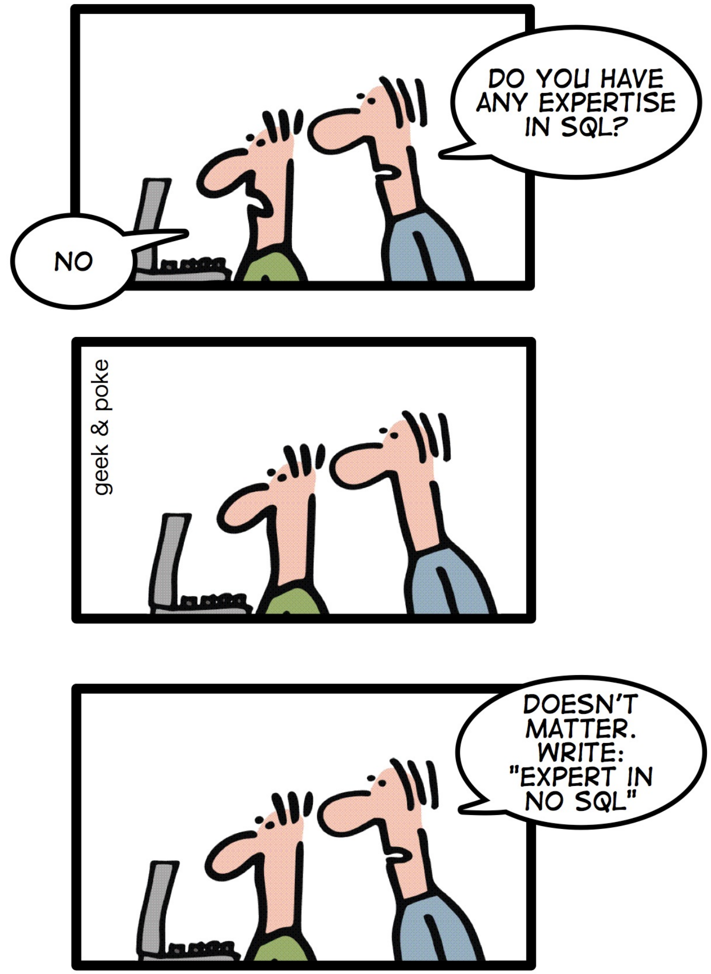


Source: Gerardnico.com

Summary

- *Three 291 students walked into a noSQL bar. They quickly walked out because they could not find a table.*
- The term noSQL started being used in 2009
- Desirable properties
  - Network based databases,
  - Schema free access
  - Batch (and scalable) processing

HOW TO WRITE A CV



Leverage the NoSQL boom