Scalable data processing, NoSQL

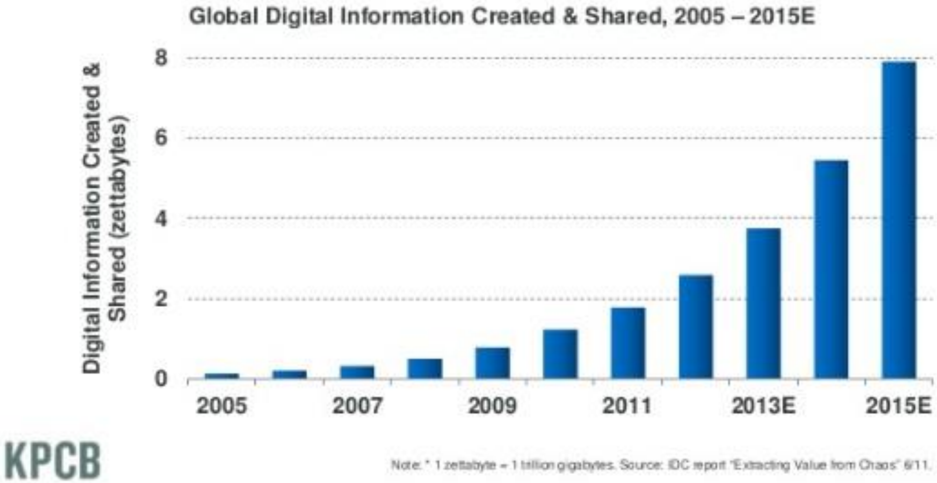
Gergely Lukács
Pázmány Péter Catholic University
Faculty of Information Technology
Budapest, Hungary
lukacs@itk.ppke.hu

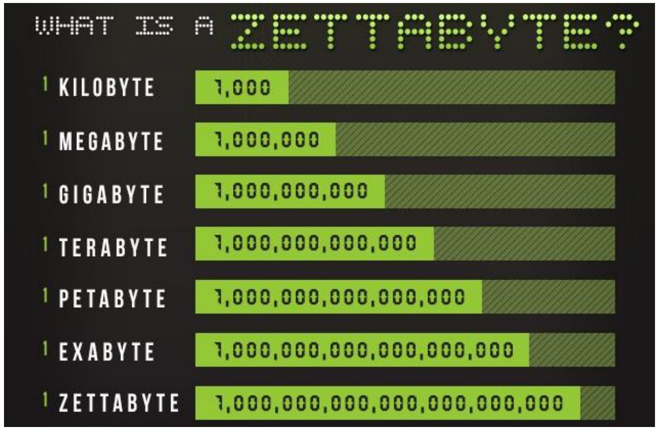
NoSQL databases

How much data?

- Google processes 20 PB a day (2008)
- Wayback Machine has 3 PB + 100 TB/month (3/2009)
- Facebook has 2.5 PB of user data + 15 TB/day (4/2009)
- eBay has 6.5 PB of user data + 50 TB/day (5/2009)
- CERN's LHC will generate 15 PB a year (??)

Amount of data doubles every 20 months





NoSQL: The Name

- "SQL" = Traditional relational DBMS
  - efficient, reliable, convenient, and safe multi-user storage of and access to massive amounts of persistent data
- Recognition over past decade or so:
  Not every data management/analysis problem is best solved using a traditional relational DBMS
  - Web-based systems!
- "NoSQL" ("No SQL")
  - Not using traditional relational DBMS
  - **Not Only SQL**

NoSQL – Definition ?

- Heterogeneous group of concepts, systems
  - Key-value stores
  - Wide column stores
  - Document stores
  - …

NoSQL – Advantages

- Depend on system/category (heterogeneous concept!!)

- Higher performance
- Easy distribution of data on nodes (sharding): scalability, fault tolerance
- Flexibility: schema free data model
- Simpler administration

NoSQL – Methods

- No normalied relational data model
- Transaction management relaxed (ACID->BASE), fewer garanties
  - **Basically available:** Nodes in the a distributed environment can go down, but the whole system shouldn't be affected.
  - **Soft State** (scalable): The state of the system and data changes over time.
  - **Eventual Consistency**: Given enough time, data will be consistent across the distributed system.
- Less powerful querying

CAP Theorem

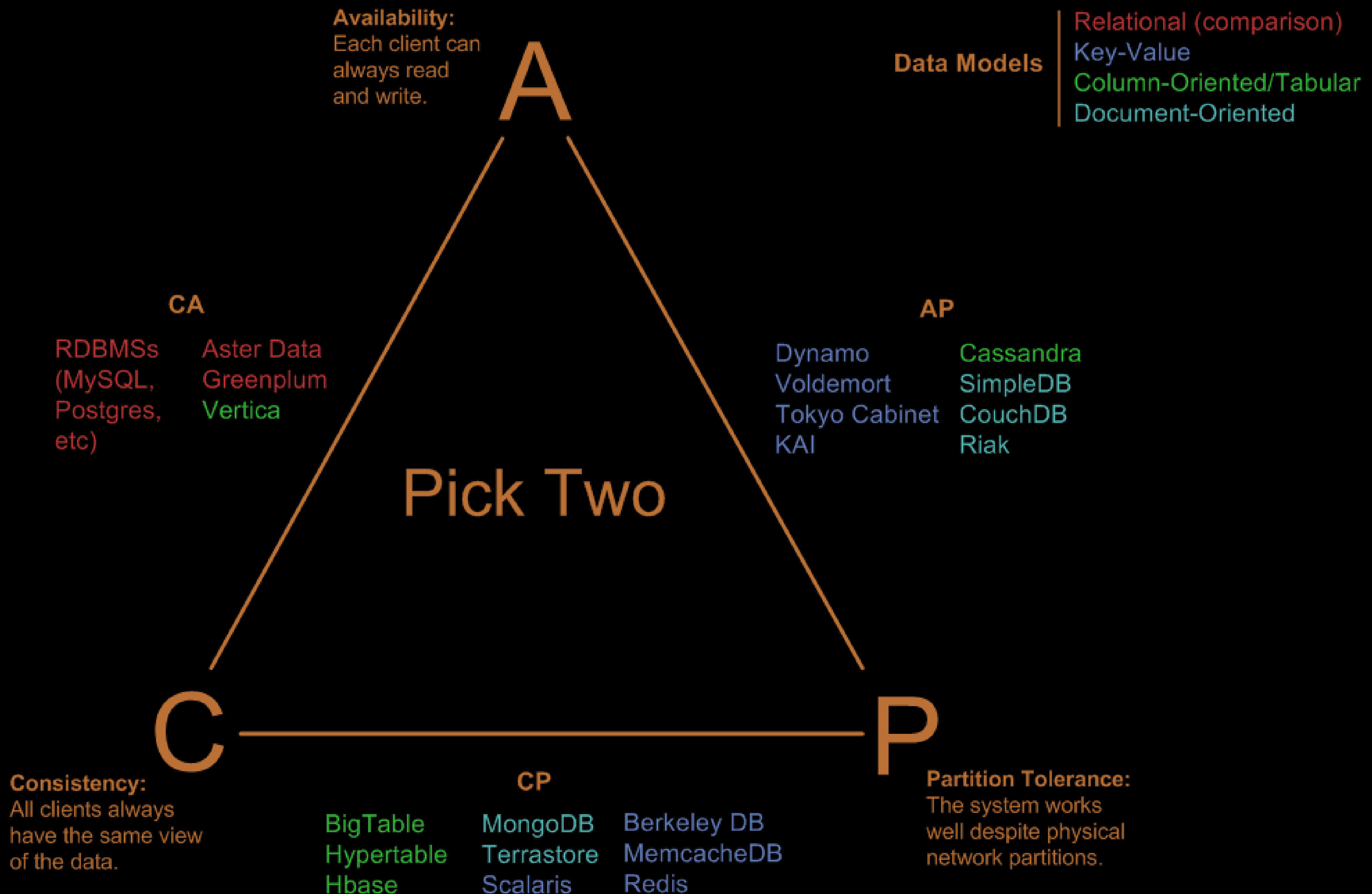
- Also known as Brewer's Theorem by Prof. Eric Brewer, published in 2000 at University of Berkeley.
- "Of three properties of a shared data system: data consistency, system availability and tolerance to network partitions, only two can be achieved **at any given moment**."
- Proven by Nancy Lynch et al. MIT labs.

- http://www.cs.berkeley.edu/~brewer/cs262b-2004/PODC-keynote.pdf

CAP Semantics

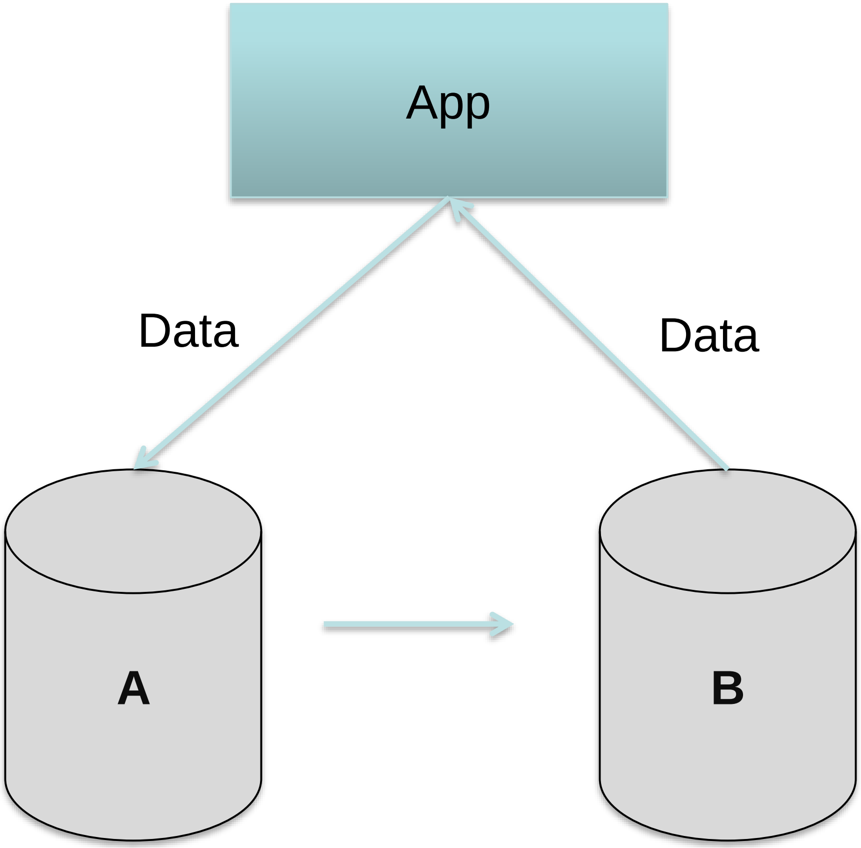
- **C**onsistency: Clients should read the same data. There are many levels of consistency.
  - Strict Consistency – RDBMS.
  - Tunable Consistency – Cassandra.
  - Eventual Consistency – Amazon Dynamo.
- **A**vailability: Data to be available.
- **P**artition Tolerance: Data to be partitioned across network segments due to network failures.

Visual Guide to NoSQL Systems



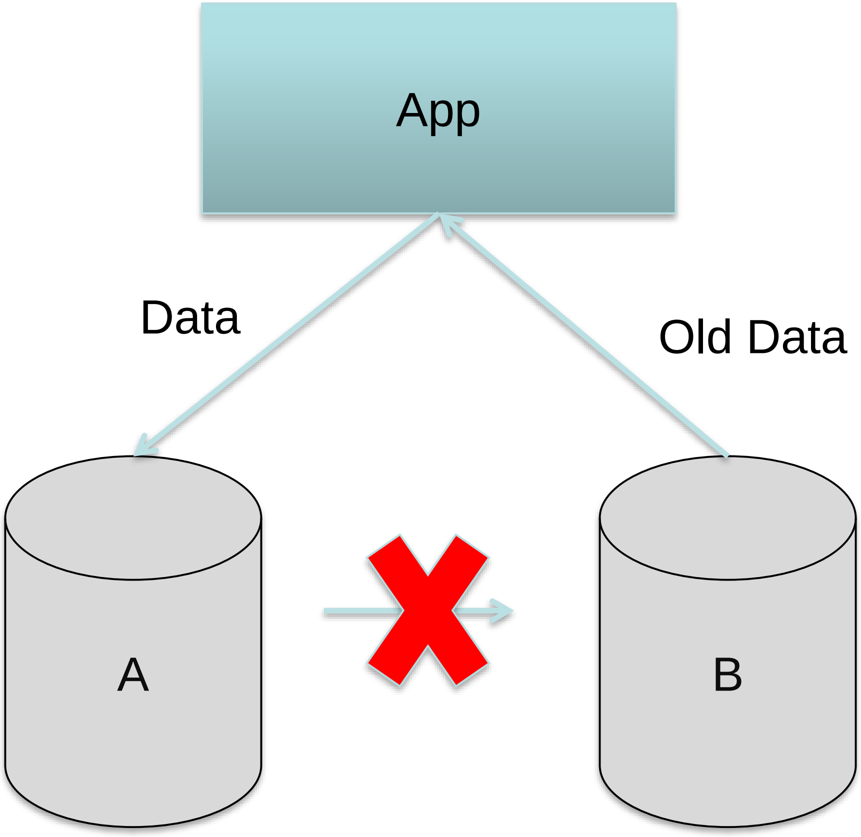
A Simple Proof

Consistent and available
No partition.



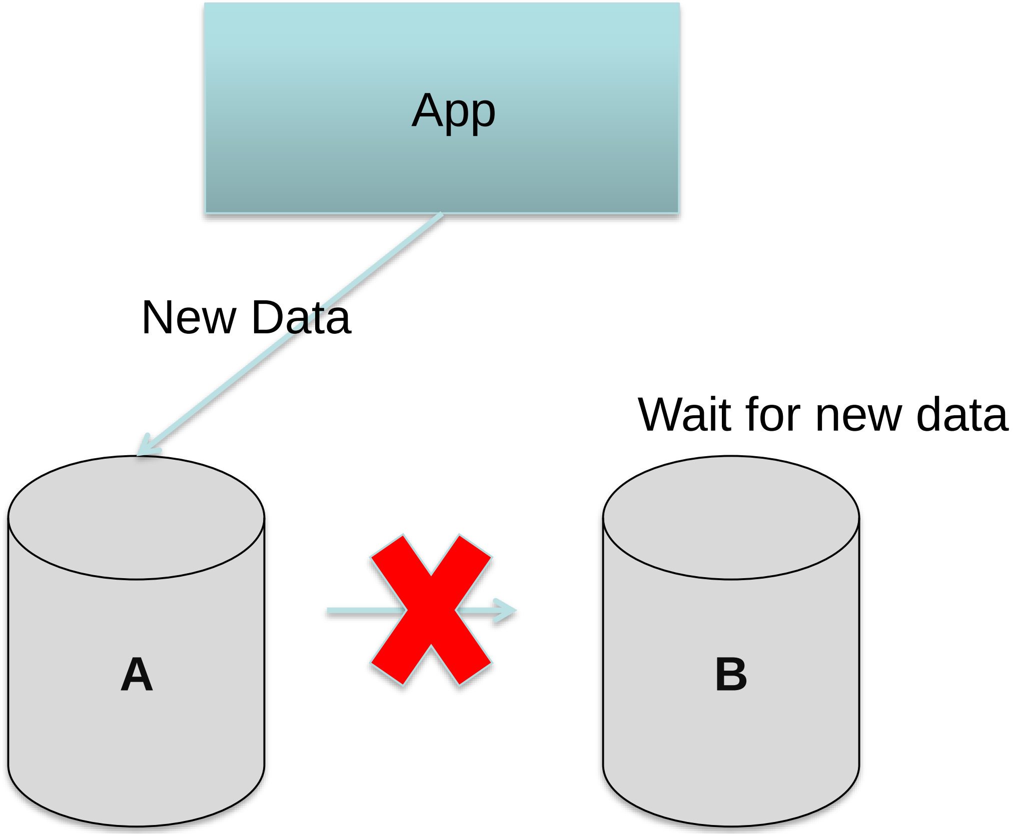
A Simple Proof

Available and partitioned
Not consistent, we get back old data.



A Simple Proof

Consistent and partitioned
Not available, waiting…



Google Cloud Spanner

Spanner is Google's highly available global SQL database [CDE+12]. It manages replicated data at great scale, both in terms of size of data and volume of transactions. It assigns globally consistent real-time timestamps to every datum written to it, and clients can do globally consistent reads across the entire

database without locking.

The CAP theorem [Bre12] says that you can only have two of the three desirable properties of:

- C: Consistency, which we can think of as serializability for this discussion;
- A: 100% availability, for both reads and updates;
- P: tolerance to network partitions.

This leads to three kinds of systems: CA, CP and AP, based on what letter you leave out. Note that you are not entitled to 2 of 3, and many systems have zero or one of the properties. For **distributed systems** over a "wide area", it is generally viewed that **partitions are inevitable**, although not necessarily common [BK14]. Once you believe that partitions are inevitable, any distributed system must be prepared to forfeit either consistency (AP) or availability (CP), which is not a choice anyone wants to make. In fact, the original point of the CAP theorem was to get designers to take this tradeoff seriously. But there are two important caveats: first, you **only** need forfeit something **during an actual partition,** and even then there are many mitigations (see the "12 years" paper [Bre12]). Second, the actual theorem is about 100% availability, while the interesting discussion here is about the **tradeoffs involved for realistic high availability**.

Key-value stores

Examples for Data

Extremely simple interface

- Data model: (key, value) pairs

Color	Red
Age	18
Size	Large
Name	Smith
Title	The Brown Dog

user1923_color	Red
user1923_age	18
user3371_color	Blue
user4344_color	Brackish
user1923_height	6' 0"
user3371_age	34

- Operations
  - Insert(key,value)
  - Fetch(key)
  - Update(key, value)
  - Delete(key)

Key-Value Stores

Implementation: efficiency, scalability, fault-tolerance

- Records distributed to nodes based on key
- Replication
- Single-record transactions, “eventual consistency”

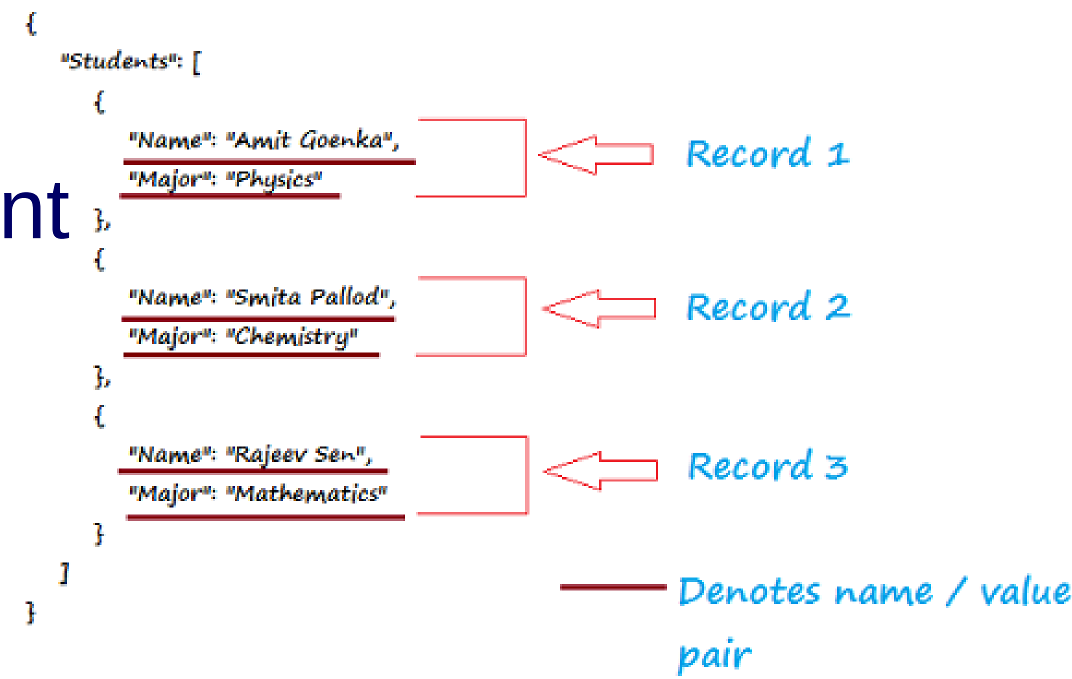
52 systems in ranking, April 2016

Rank Apr 2016	Rank Mar 2016	Rank Apr 2015	DBMS	Database Model	Score Apr 2016	Score Mar 2016	Score Apr 2015
1.	1.	1.	Redis	Key-value store	111.24	+5.02	+16.69
2.	2.	2.	Memcached	Key-value store	28.01	-1.23	-6.04
3.	3.	3.	Amazon DynamoDB	Multi-model	23.12	+0.89	+8.54
4.	4.	4.	Riak KV	Key-value store	11.49	-0.60	-1.60
5.	5.	↑ 6.	Hazelcast	Key-value store	6.68	-0.13	+1.00
6.	6.	↓ 5.	Ehcache	Key-value store	6.46	-0.25	-1.25
7.	7.	↑ 8.	OrientDB	Multi-model	6.31	-0.35	+2.93
8.	8.	↑ 11.	Aerospike	Key-value store	4.20	+0.10	+1.71
9.	↑ 10.	9.	Oracle Coherence	Key-value store	3.13	-0.24	-0.19
10.	↓ 9.	↓ 7.	Berkeley DB	Key-value store	3.06	-0.38	-0.86
11.	11.	↓ 10.	Amazon SimpleDB	Key-value store	2.96	+0.05	-0.24
12.	12.	12.	Oracle NoSQL	Key-value store	2.51	-0.02	+0.39

Document stores

Document Stores

- Like Key-Value Stores except value is document
  - [XML]
  - [YAML]
  - [JSON]
  - [BSON]
  - binary forms
    - PDF
    - Microsoft Office documents (MS Word, Excel, and so on).



Document Stores

- Data model: (key, document) pairs
  - Basic operations:
    - Insert(key,document), Fetch(key), Update(key), Delete(key)
  - Also Fetch based on document contents

39 systems in ranking, April 2016

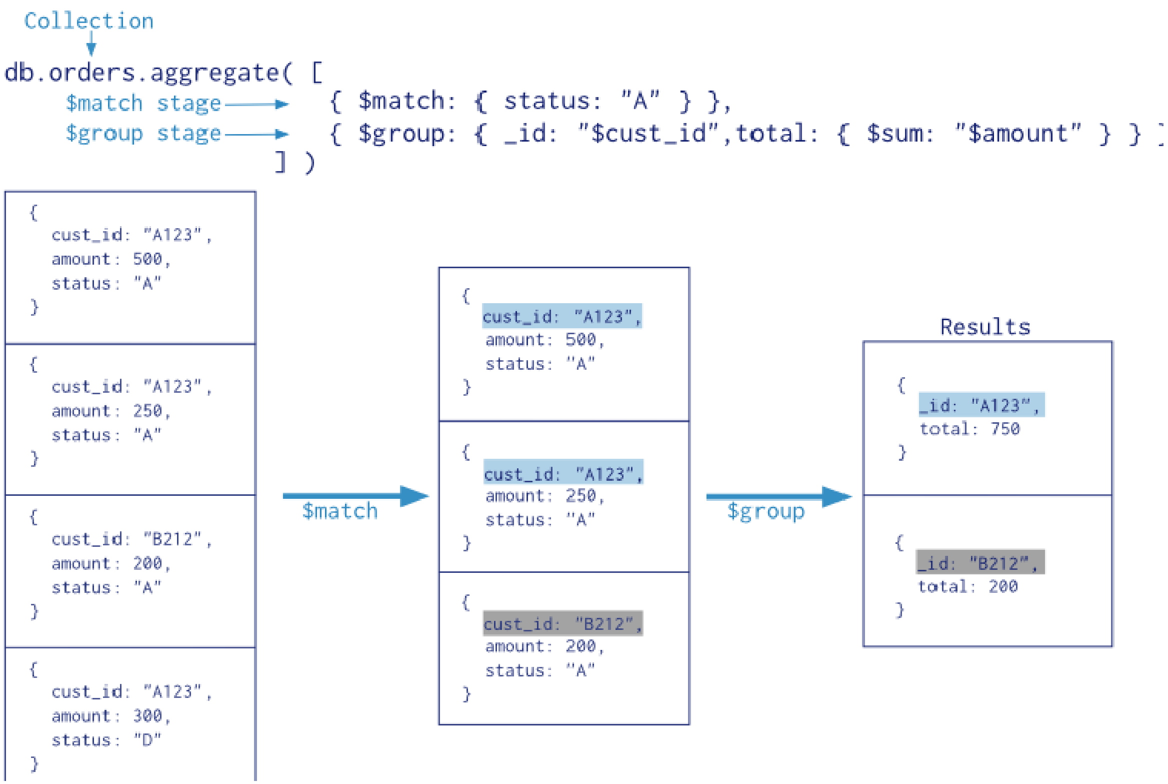
Rank Apr 2016	Rank Mar 2016	Rank Apr 2015	DBMS	Database Model	Score Apr 2016	Score Mar 2016	Score Apr 2015
1.	1.	1.	MongoDB	Document store	312.44	+7.11	+33.85
2.	2.	↑ 3.	Couchbase	Document store	25.02	-0.78	-0.55
3.	↑ 4.	↑ 4.	Amazon DynamoDB	Multi-model	23.12	+0.89	+8.54
4.	↓ 3.	↓ 2.	CouchDB	Document store	22.36	-1.02	-4.58
5.	5.	5.	MarkLogic	Multi-model	9.12	-0.25	-1.09

MongoDB

- High performance
- High availability
- Horizontal scalability
  - Sharding: distributing data across a cluster of machines
- Rich query language
  - Data aggregation
  - Text search
  - Geospatial queries

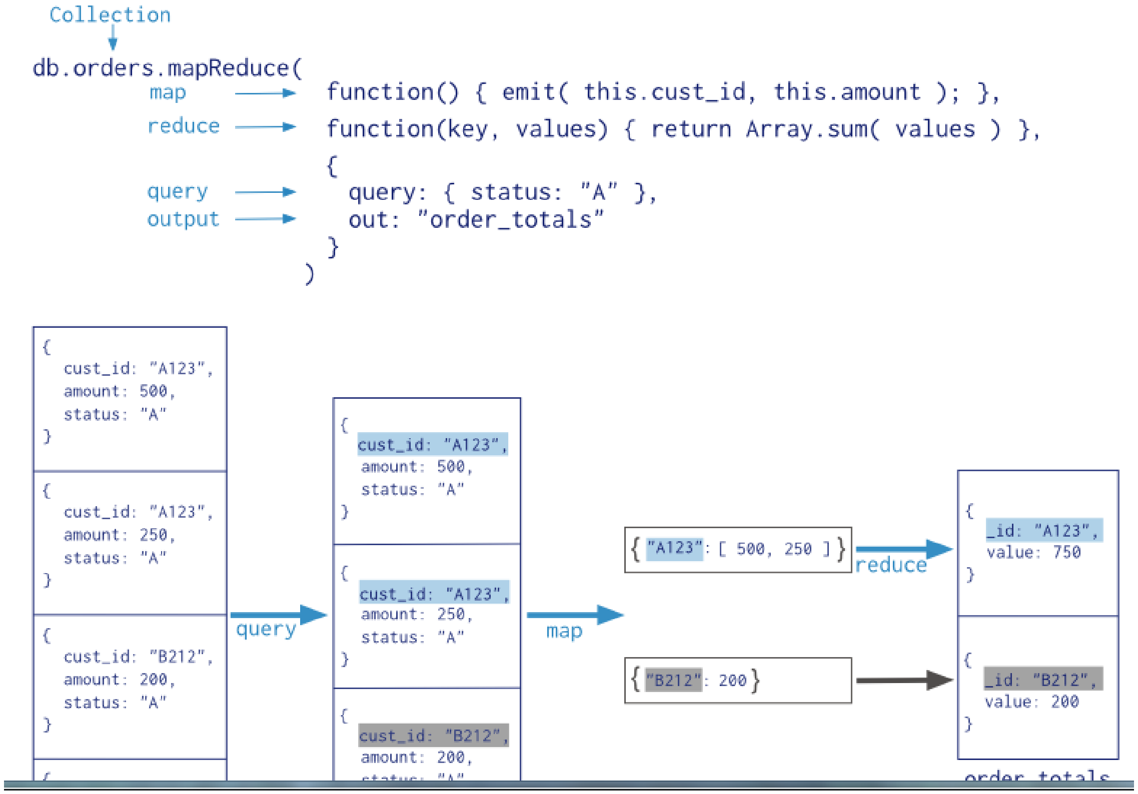
MongoDB - aggregation

- Aggregation pipeline



MongoDB - aggregation

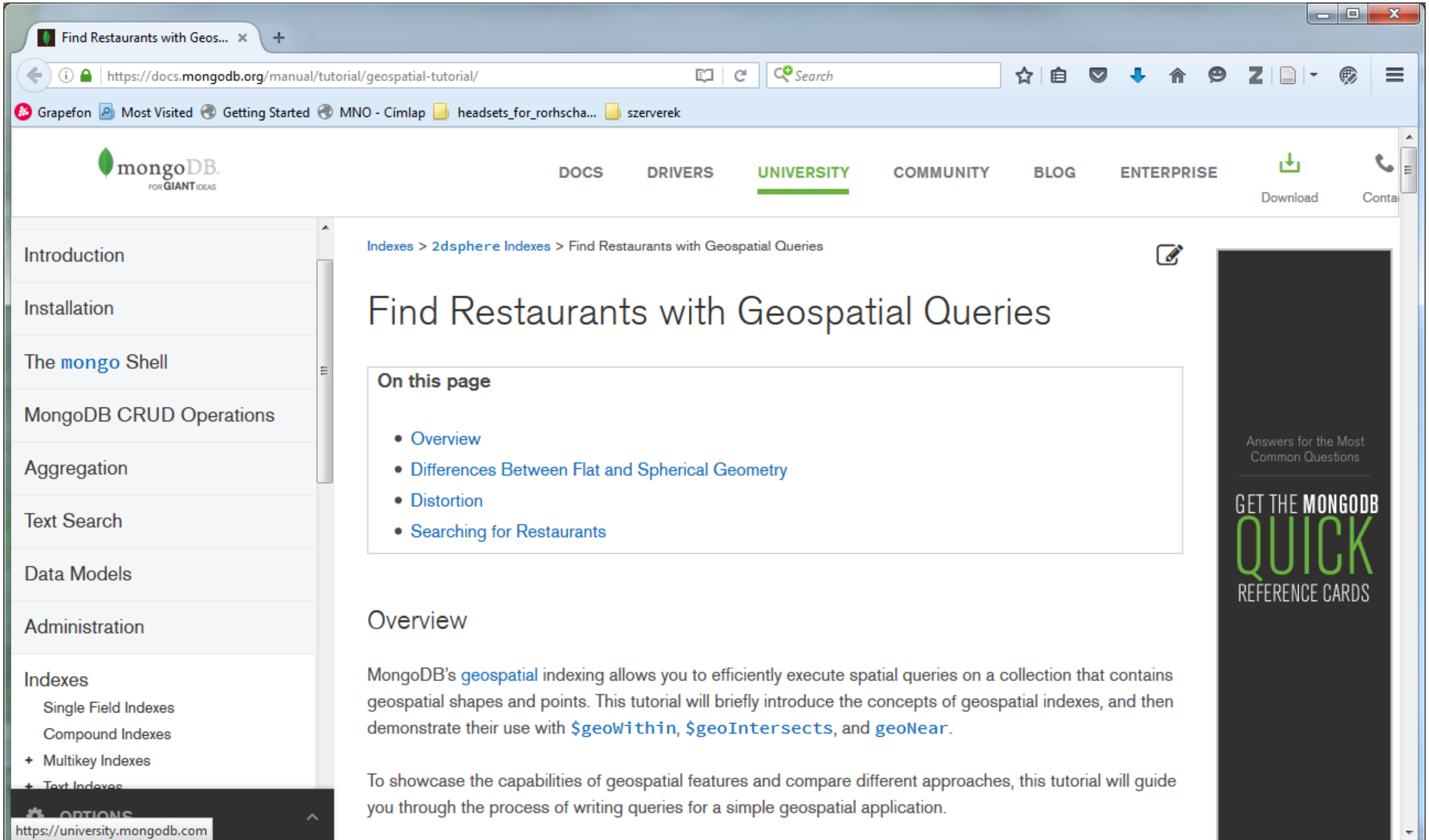
- Aggregation MapReduce



MongoDB - aggregation

- Single purpose aggregation operations
  - Db.collection.count()
  - Db.collection.group()
  - Db.collection.distinct()

MongoDB – geospatial queries



Wide column stores

- Key-value database
- Columns: name, format can vary from row to row
- Apache Cassandra