CS460: Intro to Database Systems

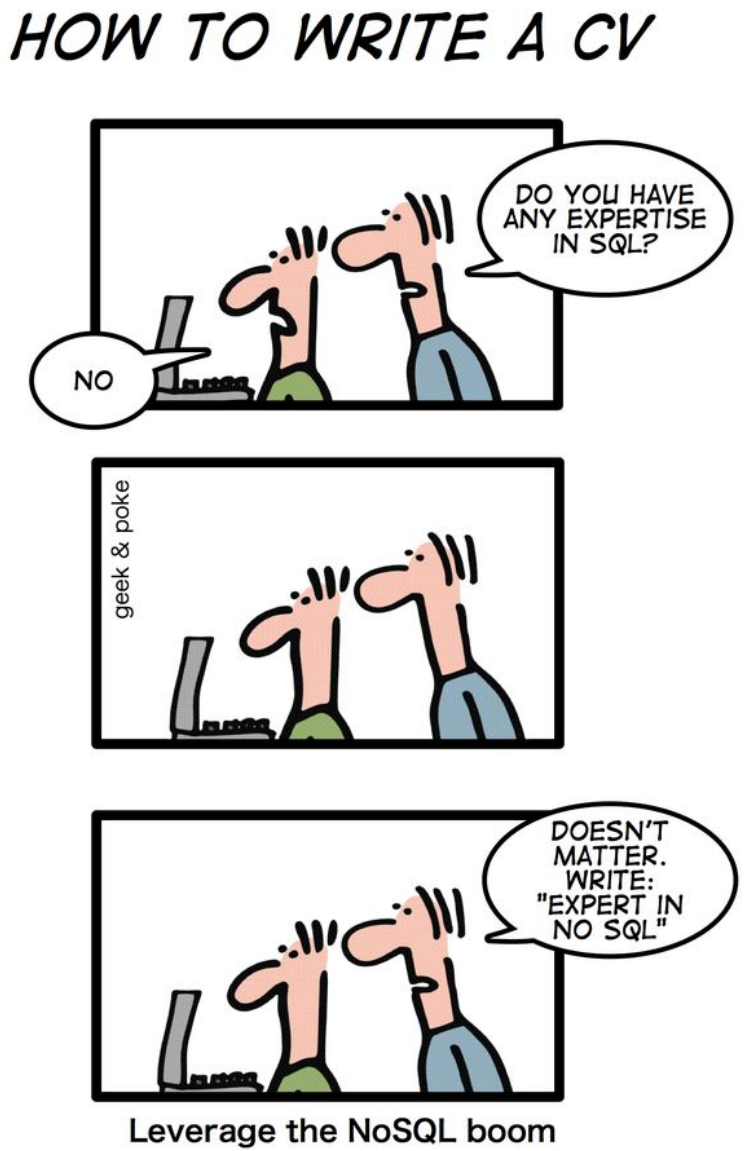
Class 25: NoSQL Systems

Instructor: Manos Athanassoulis

https://bu-disc.github.io/CS460/

What is NoSQL?

from “Geek and Poke”



What is NoSQL?

An emerging “movement” around non-relational software for Big Data

Roots are in the Google and Amazon homegrown software stacks

Wikipedia: “A NoSQL database provides a mechanism for storage and retrieval of data that use looser consistency models than traditional relational databases in order to achieve horizontal scaling and higher availability. Some authors refer to them as "Not only SQL" to emphasize that some NoSQL systems do allow SQL-like query language to be used.”

NoSQL Stores

offer an easy to program storage model

simplification of relational

two attributes (a key and a value)

value has variable size

NoSQL features

Scalability is crucial!

- load increased rapidly for many applications

Large servers are expensive

Solution: use clusters of small commodity machines

- need to partition the data and use replication (sharding)
- cheap (usually open source!)
- cloud-based storage

NoSQL features

Sometimes not a well defined schema

Allow for semi-structured data

- still need to provide ways to query efficiently (use of index methods)
- need to express specific types of queries easily

Scalability

Often cited as the main reason for moving from DB technology to NoSQL

DB Position: there is no reason a parallel DBMS cannot scale to 1000's of nodes

NoSQL Position: a) Prove it; b) it will cost too much anyway

Flavors of NoSQL

Four main types:

- key-value stores
- document databases
- column-family (aka big-table) stores
- graph databases

Here we will talk more about “Document” databases (MongoDB)

Key-Value Stores

There are many systems like that:

Redis, MemcacheDB, Amazon's DynamoDB, Voldemort

Simple data model: key/value pairs

the DBMS does not attempt to interpret the value

Queries are limited to query by key

- get/put/update/delete a key/value pair
- iterate over key/value pairs

Document Databases

Examples include:

MongoDB, CouchDB, Terrastore

Special type of key/value that value is a document.

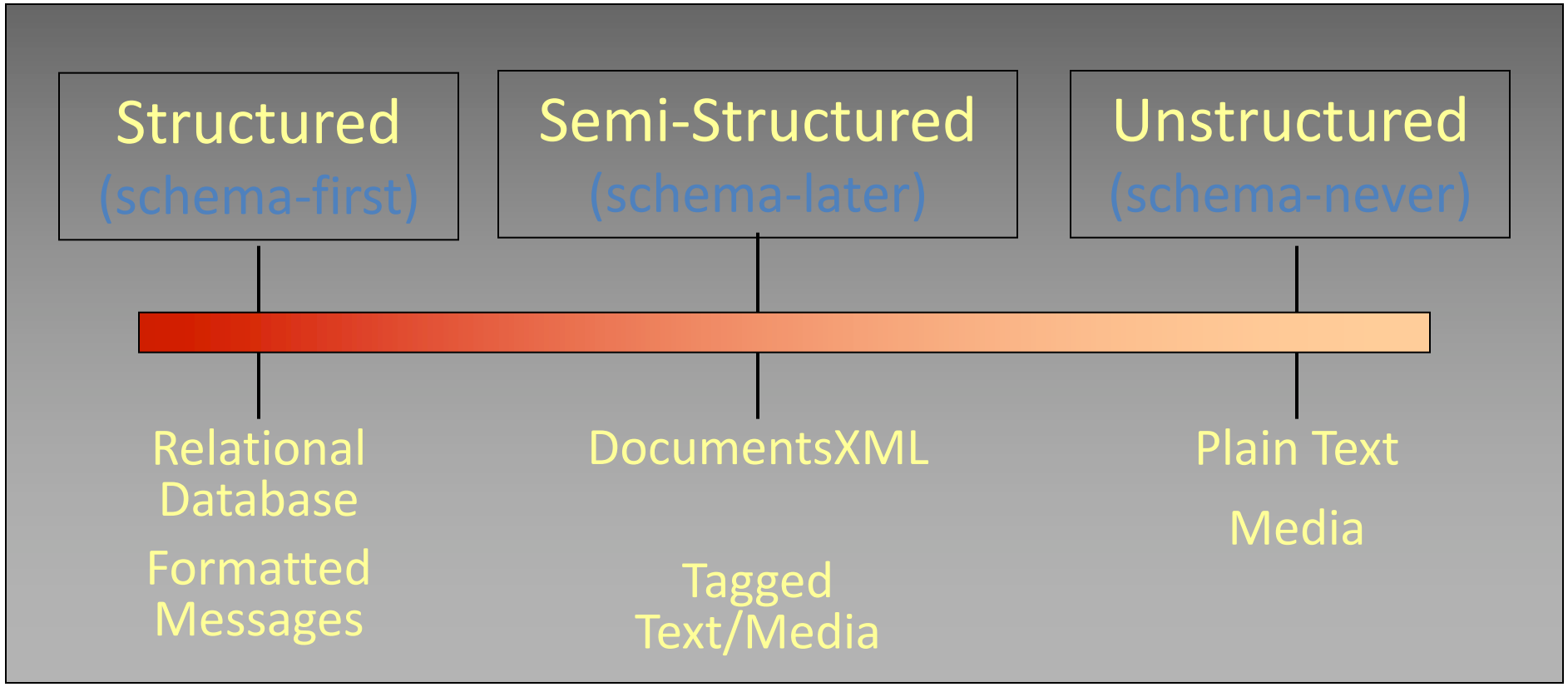
- use some sort of semi-structured data model: XML/JSON
- the value can be examined and used by the system (unlike in key/data stores)

Queries based on key (as in key/value stores), but also on the document (value).

Here again, there is support for sharding and replication.

- the sharding can be based on values within the document

The Structure Spectrum



MongoDB (An example of a Document Database)

Data are organized in collections. A collection stores a set of documents.

Collection (like table) and document (like record)

- but: each document can have a different set of attributes even in the same collection
- Semi-structured schema!

Only requirement: every document should have an "_id" field

- hu**mongo**us => Mongo

Example mongodb

{ "_id”:ObjectId("4efa8d2b7d284dad101e4bc9"),
"Last Name": ” Cousteau",
"First Name": ” Jacques-Yves",
"Date of Birth": ”06-1-1910" },

{ "_id": ObjectId("4efa8d2b7d284dad101e4bc7"),
"Last Name": "PELLERIN",
"First Name": "Franck",
"Date of Birth": "09-19-1983",
"Address": "1 chemin des Loges",
"City": "VERSAILLES" }

Example Document Database: MongoDB

Key features include:

- JSON-style documents
  - actually uses BSON (JSON's binary format)
- replication for high availability
- auto-sharding for scalability
- document-based queries
- can create an index on any attribute for faster reads

under the hood, a simple key-value store called WiredTiger!
design based on LSM-trees

MongoDB Terminology

relational term <==> MongoDB equivalent

---

database <==> database

table <==> collection

row <==> document

attributes <==> fields (field-name:value pairs)

primary key <==> the _id field, which is the key associated with the document

JSON

JSON is an alternative data model for semi-structured data

- JavaScript Object Notation

Built on two key structures:

- an object, which is a sequence of name/value pairs

  { ”_id": "1000", "name": "Sanders Theatre", "capacity": 1000 }
- an array of values ["123", "222", "333"]

A value can be:

- an atomic value: string, number, true, false, null
- an object
- an array

The _id Field

Every MongoDB document must have an _id field.

- its value must be unique within the collection
- acts as the primary key of the collection
- it is the key in the key/value pair

If you create a document without an _id field:

- MongoDB adds the field for you
- assigns it a unique BSON (binary JSON) ObjectID
- example from the MongoDB shell:

```
> db.test.save({ rating: "PG-13" })
> db.test.find() { "_id" :ObjectId("528bf38ce6d3df97b49a0569"), "rating" : "PG-13" }
```

Note: quoting field names is optional (see rating above)

Capturing Relationships in MongoDB

Two options:

1. store references to other documents using their _id values

2. embed documents within other documents

Example relationships

```
{
  "_id":ObjectId("52ffc33cd85242f436000001"),
  "name": "Tom Benzamin ",
  "contact": "987654321",
  "dob": "01-01-1991"
}
```

Here is an example of embedded relationship:

```
{
  "_id":ObjectId("52ffc33cd85242f436000001"),
  "contact": "987654321",
  "dob": "01-01-1991",
  "name": "Tom Benzamin",
  "address": [
   {
     "building": "22 A, Indiana Apt",
     "pincode": 123456,
     "city": "Los Angeles",
     "state": "California"
   },
   {
     "building": "170 A, Acropolis Apt",
     "pincode": 456789,
     "city": "Chicago",
     "state": "Illinois"
   }  ]  }
```

```
{
  "_id":ObjectId("52ffc4a5d85242602e000000"),
  "building": "22 A, Indiana Apt",
  "pincode": 123456,
  "city": "Los Angeles",
  "state": "California"
}
```

And here an example of reference based

```
{
  "_id":ObjectId("52ffc33cd85242f436000001"),
  "contact": "987654321",
  "dob": "01-01-1991",
  "name": "Tom Benzamin",
  "address_ids": [
    ObjectId("52ffc4a5d85242602e000000"),
    ObjectId("52ffc4a5d85242602e000001")
  ]
}
```

Queries in MongoDB

Each query can only access a single collection of documents.

Use a method called

```
> db.collection.find(<selection>, <projection>)
```

Example: find the names of all R-rated movies:

```
> db.movies.find({ rating: 'R' }, { name: 1 })
```

Projection

Specify the name of the fields that you want in the output with 1 (0 hides the value)

Example:

```
> db.movies.find({},{"title":1,_id:0})
```

(will report the title but not the id)

Selection

You can specify the condition on the corresponding attributes using the find:

```
> db.movies.find({ rating: "R", year: 2000 }, { name: 1, runtime: 1 })
```

Operators for other types of comparisons:

MongoDB	SQL equivalent
$gt, $gte	>, >=
$lt, $lte	<, <=
$ne	!=

Example: find the names of movies with an earnings <= 200000

```
> db.movies.find({ earnings: { $lte: 200000 }})
```

For logical operators $and, $or, $nor

use an array of conditions and apply the logical operator among the array conditions:

```
> db.movies.find({ $or: [ { rating: "R" }, { rating: "PG-13" } ] })
```

Aggregation

Recall the aggregate operators in SQL: AVG(), SUM(), etc.

More generally, aggregation involves computing a result from a collection of data.

MongoDB supports several approaches to aggregation:

- single-purpose aggregation methods
- an aggregation pipeline
- map-reduce

Aggregation pipelines are more flexible and useful (see next):

https://docs.mongodb.com/manual/core/aggregation-pipeline/

Simple Aggregations

db.collection.count(<selection>)

returns the number of documents in the collection

that satisfy the specified selection document

Example: how may R-rated movies are shorter than 90 minutes?

```
> db.movies.count({ rating: "R", runtime: { $lt: 90 }})
```

db.collection.distinct(<field>, <selection>)

returns an array with the distinct values of the specified field

in documents that satisfy the specified selection document

if omit the query, get all distinct values of that field

Example: which actors have been in one or more of the top 10 grossing movies?

```
> db.movies.distinct("actors.name", { earnings_rank: { $lte: 10 }})
```

Aggregation Pipeline

A very powerful approach to write queries in MongoDB is to use pipelines.

We execute the query in stages.

Every stage gets as input some documents, applies filters/aggregations/projections and outputs some new documents.

These documents are the input to the next stage (next operator) and so on

Similar to a traditional query plan. But always with one child (no joins!)

Aggregation Pipeline example

Example for the zipcodes database:

```
> db.zipcodes.aggregate( [
  { $group: { _id: "$state", totalPop: { $sum: "$pop" } } },
  { $match: { totalPop: { $gte: 10*1000*1000 } } }
] )
```


```
{
 "_id": "10280",
 "city": "NEW YORK",
 "state": "NY",
 "pop": 5574,
 "loc": [
  -74.016323,
  40.710537
 ]
}
```


Here we use group_by to group documents per state, compute sum of population and output documents with _id, totalPop (_id has the name of the state). The next stage finds a match for all states the have more than 10M population and outputs the state and total population.

More here: https://docs.mongodb.com/manual/tutorial/aggregation-zip-code-data-set/

continued:

Output example:

```
{
  "_id" : ”NY",
  "totalPop" : 19750000
}
```

In SQL:

```
SELECT state, SUM(pop) AS totalPop
FROM zipcodes
GROUP BY state
HAVING totalPop >= (10*1000*1000)
```

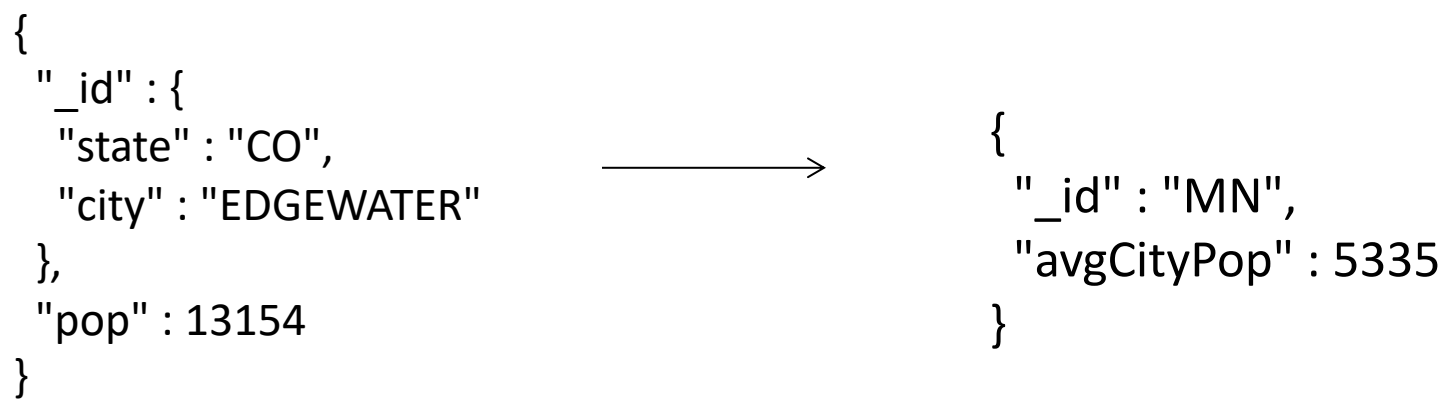
```
db.zipcodes.aggregate( [
   { $group: { _id: "$state", totalPop: { $sum: "$pop" } } },
   { $match: { totalPop: { $gte: 10*1000*1000 } } }
] )
```

more examples:

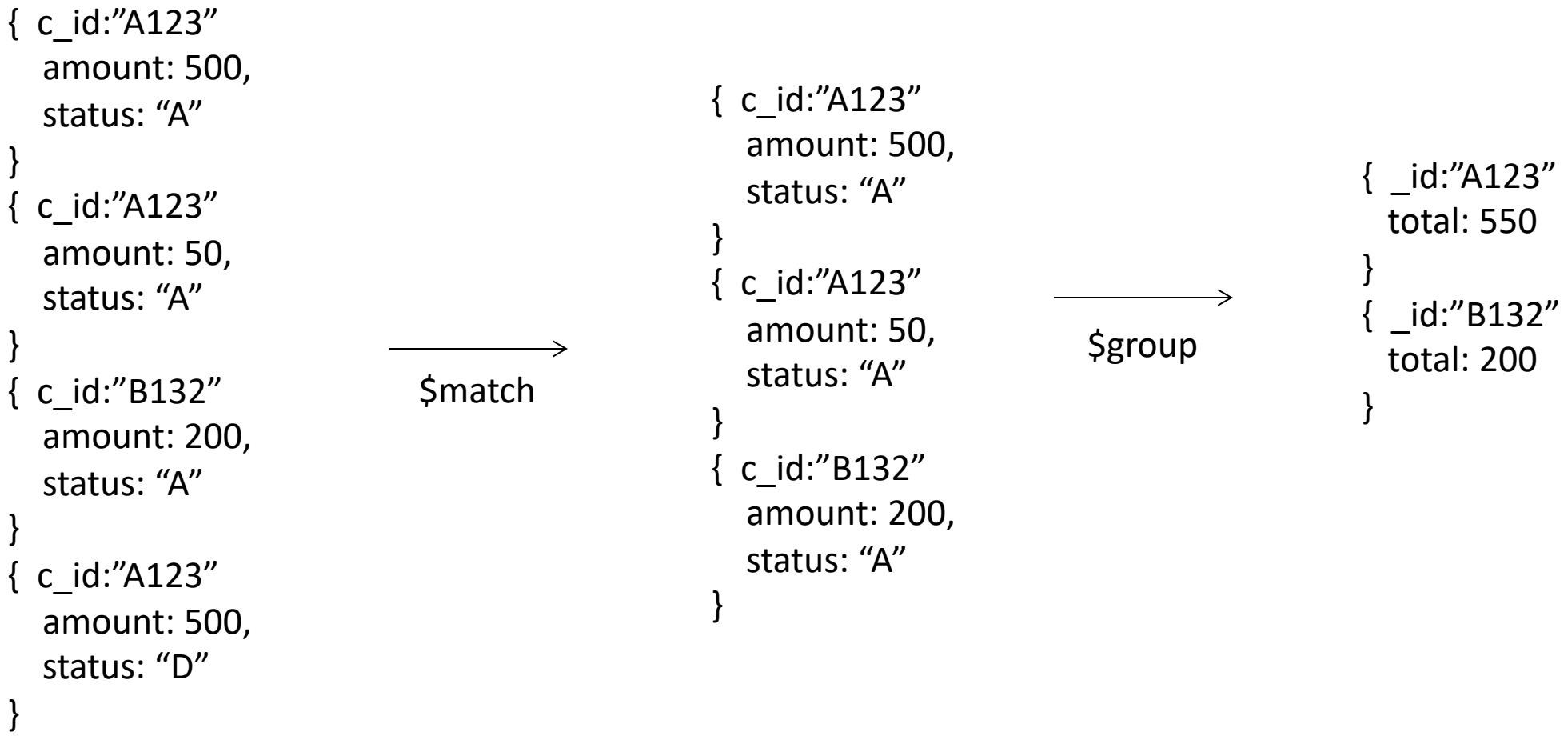
```
db.zipcodes.aggregate( [
   { $group: { _id: { state: "$state", city: "$city" }, pop: { $sum: "$pop" } } },
   { $group: { _id: "$_id.state", avgCityPop: { $avg: "$pop" } } }
] )
```

What we compute here?

First we get groups by city and state and for each group we compute the population.
Then we get groups by state and compute the average city population



Aggregation Pipeline example




```
db.orders.aggregate([ { $match: {status: "A"}}
                      { $group: {_id:"c_id", total: {$sum: $amount}}
                    ])
```

Other Structure Issues

NoSQL

a) Tables are unnatural
b) “joins” are evil
c) need to be able to “grep” my data

DB

a) Tables are a natural/neutral structure
b) data independence lets you precompute joins under the covers
c) this is a price of all the DBMS goodness you get

This is an Old Debate – Object-oriented databases, XML DBs, Hierarchical, …

Fault Tolerance

DBs: coarse-grained FT – if trouble, restart transaction

- Fewer, Better nodes, so failures are rare
- Transactions allow you to kill a job and easily restart it

NoSQL: Massive amounts of cheap HW, failures are the norm and massive data means long running jobs

- So must be able to do mini-recoveries
- This causes some overhead (file writes)