MongoDB

MongoDB: History

- A prototypical NoSQL database
- Short for hu**mongo**us
- First version in 2009!
- Still very popular
  - IPO in 2017
  - Now worth >7B in market capital (as of 2020)

MongoDB: History

- Internet & social media boom led to a demand for
  - Rapid data model evolution: "a move fast and break things" mentality to system dev
    - E.g., adding a new attrib to a Facebook profile
    - Contrary to DBMS wisdom of declaring schema upfront and changing rarely (costly!)
  - BASE rather than ACID

- Early version centered around storing and querying json documents quickly
- Made several tradeoffs for speed
  - No joins ➔ now support left outer joins
  - Limited query opt ➔ still limited, but many improvements
  - No txn support apart from atomic writes to json docs ➔ limited support for multi-doc txns
  - No checks/schema validation ➔ now support json schema validation (rarely used!)

MongoDB: History

Bottomline:

MongoDB has now evolved into a mature "DBMS" with some different design decisions, and relearning many of the canonical DBMS lessons

We'll focus on two primary design decisions:

- The data model
- The query language

Will discuss these two to start with, then some of the architectural issues

MongoDB Data Model

MongoDB	DBMS
Database	Database
Collection	Relation
Document	Row/Record
Field	Column

Document = {…, field: value, …}

Where value can be:

- Atomic
- A document
- An array of atomic values
- An array of documents

{ qty : 1, status : "D", size : {h : 14, w : 21}, tags : ["a", "b"] },

Can also mix and match, e.g., array of atomics and documents, or array of arrays
[Same as the JSON data model]

Internally stored as BSON = Binary JSON

- Client libraries can directly operate on this natively

MongoDB Data Model 2

MongoDB	DBMS
Database	Database
Collection	Relation
Document	Row/Record
Field	Column

Document = {…, field: value, …}

Special field in each document: _id

- Primary key
- Will also be indexed by default
- If it is not present during ingest, it will be added
- Will be first attribute of each doc.
- This field requires special treatment during projections as we will see later

MongoDB Query Language (MQL)

- Input = collections, output = collections

- Three main types of queries in the query language
  - Retrieval: Restricted SELECT-WHERE-ORDER BY-LIMIT type queries
  - Aggregation: A bit of a misnomer; a general pipeline of operators
    - Can capture Retrieval as a special case
    - But worth understanding Retrieval queries first…
  - Updates

- All queries are invoked as
  - db.collection.operation1(…).operation2(…)…
    - collection: name of collection
  - Unlike SQL which lists many tables in a FROM clause, MQL is centered around manipulating a single collection

Some MQL Principles : Dot (.) Notation

- "." is used to drill deeper into nested docs/arrays
- Recall that a value could be atomic, a nested document, an array of atomics, or an array of nested documents
- Examples:
  - "instock.qty" ➔ qty field within instock
    - Applies only when instock is a nested doc or an array of nested docs
      - If instock is a nested doc or object, then qty could be nested field
      - If instock is an array of nested docs, then qty could be a nested field within documents in the array
  - "instock.1" ➔ second element within the instock array
    - Element could be an atomic value or a nested document
  - "instock.1.qty" ➔ qty field within the second document within the instock array
- Note: such dot expressions need to be in quotes

Some MQL Principles : Dollar ($) Notation

- $ indicates that the string is a special keyword
  - E.g., $gt, $lte, $add, $elemMatch, …
- Used as the "field" part of a "field : value" expression
- So if it is a binary operator, it is *usually* done as:
  - {LOperand : { $keyword : ROperand}}
  - e.g., {qty : {$gt : 30}}
- Alternative: arrays
  - {$keyword : [argument list]}
  - e.g., {$add : [1, 2]}

- Exception: $fieldName, used to refer to a previously defined field on the value side
  - Purpose: disambiguation
  - Only relevant for aggregation pipelines
  - Let's not worry about this for now.

Retrieval Queries Template

db.collection.**find**(<*predicate*>, optional <*projection*>)

returns documents that match <*predicate*>

keep fields as specified in <*projection*>

both <*predicate*> and <*projection*> expressed as documents

in fact, most things are documents!

db.inventory.find({ })

returns all documents

```
> db.inventory.find()
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d993"), "item" : "journal", "qty" : 25, "size" : { "h" : 14, "w" : 21, "uom" : "cm" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d994"), "item" : "notebook", "qty" : 50, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d995"), "item" : "paper", "qty" : 100, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d996"), "item" : "planner", "qty" : 75, "size" : { "h" : 22.85, "w" : 30, "uom" : "cm" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d997"), "item" : "postcard", "qty" : 45, "size" : { "h" : 10, "w" : 15.25, "uom" : "cm" }, "status" : "A" }
```

Retrieval Queries: Basic Queries

```
> db.inventory.find()
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d993"), "item" : "journal", "qty" : 25, "size" : { "h" : 14, "w" : 21, "uom" : "cm" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d994"), "item" : "notebook", "qty" : 50, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d995"), "item" : "paper", "qty" : 100, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d996"), "item" : "planner", "qty" : 75, "size" : { "h" : 22.85, "w" : 30, "uom" : "cm" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d997"), "item" : "postcard", "qty" : 45, "size" : { "h" : 10, "w" : 15.25, "uom" : "cm" }, "status" : "A" }
```

db.collection.find(**<predicate>**, optional <projection>)

- find({ status : "D"})
  - all documents with status D ➔ paper, planner
- find ({ qty : {$gte : 50} })
  - all documents with qty >= 50 ➔ notebook, paper, planner
- find ({ status : "D", qty : {$gte : 50} })
  - all documents that satisfy both ➔ paper, planner
- find({ $or: [{ status : "D" }, { qty : { $lt : 30 } }] })
  - all documents that satisfy either ➔ journal, paper, planner

```
> db.inventory.find( { $or: [ { status: "D" }, { qty: { $lt: 30 } } ] } )
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d993"), "item" : "journal", "qty" : 25, "size" : { "h" : 14, "w" : 21, "uom" : "cm" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d995"), "item" : "paper", "qty" : 100, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d996"), "item" : "planner", "qty" : 75, "size" : { "h" : 22.85, "w" : 30, "uom" : "cm" }, "status" : "D" }
```

Retrieval Queries: Nested Documents

```
> db.inventory.find()
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d993"), "item" : "journal", "qty" : 25, "size" : { "h" : 14, "w" : 21, "uom" : "cm" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d994"), "item" : "notebook", "qty" : 50, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "A" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d995"), "item" : "paper", "qty" : 100, "size" : { "h" : 8.5, "w" : 11, "uom" : "in" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d996"), "item" : "planner", "qty" : 75, "size" : { "h" : 22.85, "w" : 30, "uom" : "cm" }, "status" : "D" }
{ "_id" : ObjectId("5fb55fad75b4eb537dc3d997"), "item" : "postcard", "qty" : 45, "size" : { "h" : 10, "w" : 15.25, "uom" : "cm" }, "status" : "A" }
```

db.collection.find(**<predicate>**, optional <projection>)

- find({ size: { h: 14, w: 21, uom: "cm" } })
  - exact match of nested document, including ordering of fields! ➔ journal
- find ({ "size.uom" : "cm", "size.h" : {$gt : 14 })
  - querying a nested field ➔ planner
  - Note: when using . notation for sub-fields, expression must be in quotes
  - Also note: binary operator handled via a nested document

Retrieval Queries: Arrays

```
> db.inventory.find()
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

Slightly different example dataset for Arrays and Arrays of Document Examples
db.collection.find(**<predicate>**, optional <projection>)

- find({ tags: ["red", "blank"] })
  - Exact match of array ➔ notebook
- find({ tags: "red" })
  - If one of the elements matches red ➔ journal, notebook, paper, planner
- find({ tags: "red", tags: "plain" })
  - If one matches red, one matches plain ➔ paper
- find({ dim: { $gt: 15, $lt: 20 } })
  - If one element is >15 and another is <20 ➔ journal, notebook, paper, postcard
- find({ dim: {$elemMatch: { $gt: 15, $lt: 20 } } })
  - If a single element is >15 and <20 ➔ postcard
- find({ "dim.1": { $gt: 25 } })
  - If second item > 25 ➔ planner
  - Notice again that we use quotes to when using . notation

Retrieval Queries: Arrays of Documents

```
> db.inventory.find()
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

db.collection.find(**<predicate>**, optional <projection>)

- find({ instock: { loc: "A", qty: 5 } })
  - Exact match of document [like nested doc/atomic array case] ➔ journal
- find({ "instock.qty": { $gte : 20 } })
  - One nested doc has >= 20 ➔ paper, planner, postcard
- find({ "instock.0.qty": { $gte : 20 } })
  - First nested doc has >= 20 ➔ paper, planner
- find({ "instock": { $elemMatch: { qty: { $gt: 10, $lte: 20 } } } })
  - One doc has 20 >= qty >10➔ paper, journal, postcard
- find({ "instock.qty": { $gt: 10, $lte: 20 } })
  - One doc has 20 >= qty, another has qty>10 ➔ paper, journal, postcard, planner

Retrieval Queries Template: Projection

```
> db.inventory.find()
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

db.collection.find(<predicate>, **optional <projection>**)

- Use 1s to indicate fields that you want
  - Exception: _id is always present unless explicitly excluded
- OR Use 0s to indicate fields you don't want
- Mixing 0s and 1s is not allowed for non _id fields

- find({ }, {item: 1})

```
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal" }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook" }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper" }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner" }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard" }
```

- find({ }, {item: 1, _id : 0})

```
{ "item" : "journal" }
{ "item" : "notebook" }
{ "item" : "paper" }
{ "item" : "planner" }
{ "item" : "postcard" }
```

- find({ }, {item: 1, tags: 0, _id : 0})

```
Error: error: {
"ok" : 0,
"errmsg" : "Cannot do exclusion on field tags in inclusion projection",
"code" : 31254,
"codeName" : "Location31254" }
```

- find({ }, {item: 1, "instock.loc": 1, _id : 0})

```
{ "item" : "journal", "instock" : [ { "loc" : "A" }, { "loc" : "C" } ] }
{ "item" : "notebook", "instock" : [ { "loc" : "C" } ] }
{ "item" : "paper", "instock" : [ { "loc" : "A" }, { "loc" : "B" } ] }
{ "item" : "planner", "instock" : [ { "loc" : "A" }, { "loc" : "B" } ] }
{ "item" : "postcard", "instock" : [ { "loc" : "B" }, { "loc" : "C" } ] }
```

Retrieval Queries : Addendum

```
> db.inventory.find()
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

Two additional operations that are useful for retrieval:

- Limit (k) like LIMIT in SQL
  - e.g., db.inventory.find({ }).limit(1)
- Sort ({ }) like ORDER BY in SQL
  - List of fields, -1 indicates decreasing 1 indicates ascending
  - e.g., db.inventory.find({ }, {_id : 0, instock : 0}).sort({ "dim.0": -1, item: 1 })

```
{ "item" : "planner", "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "item" : "journal", "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "item" : "notebook", "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "item" : "paper", "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "item" : "postcard", "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

Retrieval Queries: Summary

find() = SELECT <projection>
FROM Collection
WHERE <predicate>
limit() = LIMIT
sort() = ORDER BY

```
db.inventory.find(
        { tags : red },
        {_id : 0, instock : 0} )
.sort ( { "dim.0": -1, item: 1 } )
.limit (2)
```

FROM
WHERE
SELECT
ORDER BY
LIMIT

MongoDB Query Language (MQL)

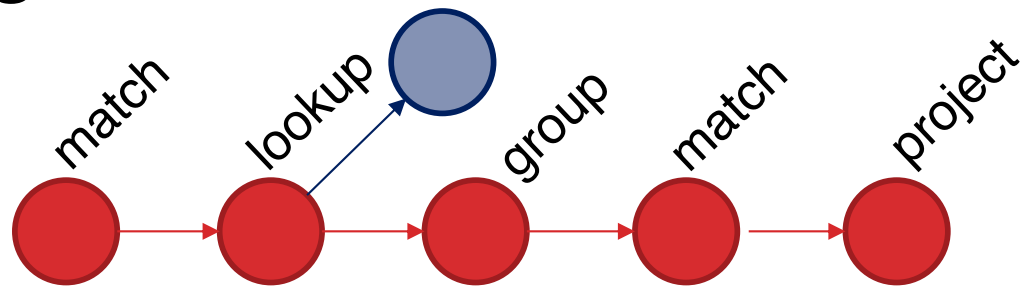
- Input = collections, output = collections

- Three main types of queries in the query language
  - Retrieval: Restricted SELECT-WHERE-ORDER BY-LIMIT type queries
  - **Aggregation**: A bit of a misnomer; a general pipeline of operators
    - Can capture Retrieval as a special case
    - But worth understanding Retrieval queries first…
  - Updates

- All queries are invoked as
  - db.collection.operation1(…).operation2(…)…
    - collection: name of collection
  - Unlike SQL which lists many tables in a FROM clause, MQL is centered around manipulating a single collection

Aggregation Pipelines

- Composed of a linear *pipeline* of *stages*
- Each stage corresponds to one of:
  - match // first arg of find ( )
  - project // second arg of find ( ) but more expressiveness
  - sort/limit // same
  - group
  - unwind
  - lookup
  - … lots more!!
- Each stage manipulates the existing collection in some way



- Syntax:

```
db.collection.aggregate ( [
 { $stage1Op: { } },
 { $stage2Op: { } },
  …
 { $stageNOp: { } }
] )
```

Next Set of Examples

```
> db.zips.find()
{ "_id" : "01022", "city" : "WESTOVER AFB", "loc" : [ -72.558657, 42.196672 ], "pop" : 1764, "state" : "MA" }
{ "_id" : "01011", "city" : "CHESTER", "loc" : [ -72.988761, 42.279421 ], "pop" : 1688, "state" : "MA" }
{ "_id" : "01026", "city" : "CUMMINGTON", "loc" : [ -72.905767, 42.435296 ], "pop" : 1484, "state" : "MA" }
{ "_id" : "01020", "city" : "CHICOPEE", "loc" : [ -72.576142, 42.176443 ], "pop" : 31495, "state" : "MA" }
{ "_id" : "01028", "city" : "EAST LONGMEADOW", "loc" : [ -72.505565, 42.067203 ], "pop" : 13367, "state" : "MA" }
{ "_id" : "01030", "city" : "FEEDING HILLS", "loc" : [ -72.675077, 42.07182 ], "pop" : 11985, "state" : "MA" }
{ "_id" : "01032", "city" : "GOSHEN", "loc" : [ -72.844092, 42.466234 ], "pop" : 122, "state" : "MA" }
{ "_id" : "01012", "city" : "CHESTERFIELD", "loc" : [ -72.833309, 42.38167 ], "pop" : 177, "state" : "MA" }
{ "_id" : "01010", "city" : "BRIMFIELD", "loc" : [ -72.188455, 42.116543 ], "pop" : 3706, "state" : "MA" }
{ "_id" : "01034", "city" : "TOLLAND", "loc" : [ -72.908793, 42.070234 ], "pop" : 1652, "state" : "MA" }
{ "_id" : "01035", "city" : "HADLEY", "loc" : [ -72.571499, 42.36062 ], "pop" : 4231, "state" : "MA" }
{ "_id" : "01001", "city" : "AGAWAM", "loc" : [ -72.622739, 42.070206 ], "pop" : 15338, "state" : "MA" }
{ "_id" : "01040", "city" : "HOLYOKE", "loc" : [ -72.626193, 42.202007 ], "pop" : 43704, "state" : "MA" }
{ "_id" : "01008", "city" : "BLANDFORD", "loc" : [ -72.936114, 42.182949 ], "pop" : 1240, "state" : "MA" }
{ "_id" : "01050", "city" : "HUNTINGTON", "loc" : [ -72.873341, 42.265301 ], "pop" : 2084, "state" : "MA" }
{ "_id" : "01054", "city" : "LEVERETT", "loc" : [ -72.499334, 42.46823 ], "pop" : 1748, "state" : "MA" }
```

One document per zipcode: 29353 zipcodes

Grouping (with match/sort) Example

```
> db.zips.find()
{ "_id" : "01022", "city" : "WESTOVER AFB", "loc" : [ -72.558657, 42.196672 ], "pop" : 1764, "state" : "MA" }
{ "_id" : "01011", "city" : "CHESTER", "loc" : [ -72.988761, 42.279421 ], "pop" : 1688, "state" : "MA" }
{ "_id" : "01026", "city" : "CUMMINGTON", "loc" : [ -72.905767, 42.435296 ], "pop" : 1484, "state" : "MA" }
```

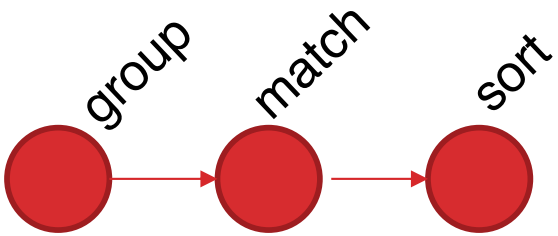
Find states with population > 15M, sort by decending order

```
db.zips.aggregate( [
{ $group: { _id: "$state", totalPop: { $sum: "$pop" } } },
{ $match: { totalPop: { $gte: 15000000 } } },
{ $sort : { totalPop : -1 } }
 ] )
```

GROUP BY

AGGS.

match after group = HAVING




```
{ "_id" : "CA", "totalPop" : 29754890 }
{ "_id" : "NY", "totalPop" : 17990402 }
{ "_id" : "TX", "totalPop" : 16984601 }
…
```

Q: what would the SQL query for this be?

SELECT state AS id, **SUM**(pop) **AS** totalPop
FROM zips
GROUP BY state
HAVING totalPop >= 15000000
ORDER BY totalPop **DESCENDING**

Grouping Syntax

$group : {
_id: <expression>, *// Group By Expression*
<field1>: { <aggfunc1> : <expression1> },
... }

Returns one document per unique group, indexed by _id

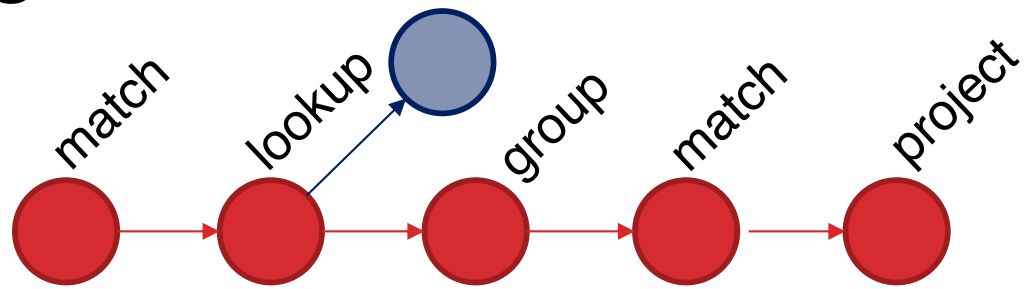
Agg.func. can be standard ops like $sum, $avg, $max

Also MQL specific ones:

- **$first** : return the first expression value per group
  - makes sense only if docs are in a specific order [usually done after sort]
- **$push** : create an array of expression values per group
  - didn't make sense in a relational context because values are atomic
- **$addToSet** : like $push, but eliminates duplicates

Aggregation Pipelines

- Composed of a linear *pipeline* of *stages*
- Each stage corresponds to one of:
  - match // first arg of find ( )
  - project // second arg of find ( ) but more expressiveness
  - sort/limit // same
  - group
  - **unwind**
  - lookup
  - … lots more!!
- Each stage manipulates the existing collection in some way



- Syntax:

```
db.collection.aggregate ( [
 { $stage1Op: { } },
 { $stage2Op: { } },
  …
 { $stageNOp: { } }
] )
```

Unwinding Arrays

```
> db.inventory.find()
{ "_id" : ObjectId("5fb59ab9f50b800678c0e196"), "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e197"), "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e198"), "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e199"), "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "_id" : ObjectId("5fb59ab9f50b800678c0e19a"), "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

Unwind expands an array by constructing documents one per element of the array

Going back to our old example with an array of tags

Notice no relational analog here: no arrays so no unwinding

[in fact, some RDBMSs do support arrays, but not in the rel. model]

```
aggregate( [
        { $unwind : "$tags" },
        { $project : {_id : 0, instock: 0}}
] )
```

```
{ "item" : "journal", "tags" : "blank", "dim" : [ 14, 21 ] }
{ "item" : "journal", "tags" : "red", "dim" : [ 14, 21 ] }
{ "item" : "notebook", "tags" : "red", "dim" : [ 14, 21 ] }
{ "item" : "notebook", "tags" : "blank", "dim" : [ 14, 21 ] }
{ "item" : "paper", "tags" : "red", "dim" : [ 14, 21 ] }
{ "item" : "paper", "tags" : "blank", "dim" : [ 14, 21 ] }
{ "item" : "paper", "tags" : "plain", "dim" : [ 14, 21 ] }
{ "item" : "planner", "tags" : "blank", "dim" : [ 22.85, 30 ] }
{ "item" : "planner", "tags" : "red", "dim" : [ 22.85, 30 ] }
{ "item" : "postcard", "tags" : "blue", "dim" : [ 10, 15.25 ] }
```

MongoDB Query Language (MQL)

- Input = collections, output = collections

- Three main types of queries in the query language
  - Retrieval: Restricted SELECT-WHERE-ORDER BY-LIMIT type queries
  - Aggregation: A bit of a misnomer; a general pipeline of operators
    - Can capture Retrieval as a special case
    - But worth understanding Retrieval queries first…
  - **Updates**

- All queries are invoked as
  - db.collection.operation1(…).operation2(…)…
    - collection: name of collection
  - Unlike SQL which lists many tables in a FROM clause, MQL is centered around manipulating a single collection

Update Queries: InsertMany

[Insert/Delete/Update] [One/Many]

- Many is more general, so we'll discuss that instead

```
db.inventory.insertMany( [
{ item: "journal", instock: [ { loc: "A", qty: 5 }, { loc: "C", qty: 15 } ], tags: ["blank", "red"], dim: [ 14, 21 ] },
{ item: "notebook", instock: [ { loc: "C", qty: 5 } ], tags: ["red", "blank"] , dim: [ 14, 21 ]},
{ item: "paper", instock: [ { loc: "A", qty: 60 }, { loc: "B", qty: 15 } ], tags: ["red", "blank", "plain"] , dim: [ 14, 21 ]},
{ item: "planner", instock: [ { loc: "A", qty: 40 }, { loc: "B", qty: 5 } ], tags: ["blank", "red"], dim: [ 22.85, 30 ] },
{ item: "postcard", instock: [ {loc: "B", qty: 15 }, { loc: "C", qty: 35 } ], tags: ["blue"] , dim: [ 10, 15.25 ] }
] );
```

Several actions will be taken as part of this insert:

- Will create inventory collection if absent [No schema specification/DDL needed!]
- Will add the _id attribute to each document added (since it isn't there)
- _id will be the first field for each document by default

Update Queries: UpdateMany

```
> db.inventory.find({}, {_id:0})
{ "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 14, 21 ] }
{ "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 14, 21 ] }
{ "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 14, 21 ] }
{ "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 10, 15.25 ] }
```

Syntax: updateMany ({<condition>}, {<change>})

```
db.inventory.updateMany (
        {"dim.0": { $lt: 15 } },
        { $set: { "dim.0": 15, status: "InvalidWidth"} }
) // if any width <15, set it to 15 and set status to InvalidWidth.
```

```
> db.inventory.find({}, {_id:0})
{ "item" : "journal", "instock" : [ { "loc" : "A", "qty" : 5 }, { "loc" : "C", "qty" : 15 } ], "tags" : [ "blank", "red" ], "dim" : [ 15, 21 ], "status" : "InvalidWidth" }
{ "item" : "notebook", "instock" : [ { "loc" : "C", "qty" : 5 } ], "tags" : [ "red", "blank" ], "dim" : [ 15, 21 ], "status" : "InvalidWidth" }
{ "item" : "paper", "instock" : [ { "loc" : "A", "qty" : 60 }, { "loc" : "B", "qty" : 15 } ], "tags" : [ "red", "blank", "plain" ], "dim" : [ 15, 21 ], "status" : "InvalidWidth" }
{ "item" : "planner", "instock" : [ { "loc" : "A", "qty" : 40 }, { "loc" : "B", "qty" : 5 } ], "tags" : [ "blank", "red" ], "dim" : [ 22.85, 30 ] }
{ "item" : "postcard", "instock" : [ { "loc" : "B", "qty" : 15 }, { "loc" : "C", "qty" : 35 } ], "tags" : [ "blue" ], "dim" : [ 15, 15.25 ], "status" : "InvalidWidth" }
```

Analogous to: UPDATE R SET <change> WHERE <condition>

MongoDB: History 4

Bottomline:

MongoDB has now evolved into a mature "DBMS" with some different design decisions, and relearning many of the canonical DBMS lessons

We'll focus on two primary design decisions:

- The data model
- The query language

Will discuss these two to start with, then **some of the architectural issues**

MongoDB Internals

- MongoDB is a distributed NoSQL database
- Collections are partitioned/sharded based on a field [range-based]
  - Each partition stores a subset of documents
- Each partition is replicated to help with failures
  - The replication is done asynchronously
  - Failures of the main partition that haven’t been propagated will be lost
- Limited heuristic-based query optimization
- Atomic writes to documents within collections by default. Multi-document txns are discouraged (but now supported).

NoSQL and MongoDB: Summary

Bottomline:

MongoDB has now evolved into a mature "DBMS" with some different design decisions, and relearning many of the canonical DBMS lessons

MongoDB has a flexible data model and a powerful (if confusing) query language.

Many of the internal design decisions as well as the query & data model can be understood when compared with DBMSs

- DBMSs provide a "gold standard" to compare against.
- In the "wild" you'll encounter many more NoSQL systems, and you'll need to do the same thing that we did here!