NoSQL Databases

Harvard Extension School

Cody Doucette, Ph.D.

Lecture designed by David G. Sullivan

The Rise of NoSQL

- Beginning in the early 2000s, web-based applications increasingly needed to deal with massive amounts of:
  - data
  - traffic / queries
- Scalability is crucial.
  - load can increase rapidly and unpredictably
- Large servers are expensive and can only grow so large.
- Solution: use clusters of small commodity machines
  - use both fragmentation/sharding and replication
  - cheaper
  - greater overall reliability
  - can take advantage of cloud-based storage

The Rise of NoSQL (cont.)

- Problem: Relational DBMSs do not scale well to large clusters.
- Google and Amazon each developed their own alternative approaches to data management on clusters.
  - Google: BigTable
  - Amazon: DynamoDB
- The papers that Google and Amazon published about their efforts got others interested in developing similar DBMSs.

  ➔ noSQL

What Does NoSQL Mean?

- Not well defined.
- Typical characteristics of NoSQL DBMSs:
  - don't use SQL / the relational model
  - open-source
  - designed for use on clusters
    - support for sharding/fragmentation and replication
  - schema-less or flexible schema
- One good overview:

  Sadalage and Fowler, *NoSQL Distilled* (Addison-Wesley, 2013).

Flavors of NoSQL

- Various taxonomies have been proposed
- Three of the main classes of NoSQL databases are:
  - key-value stores
  - document databases
  - column-family (aka big-table) stores
- Some people also include graph databases.
  - very different than the others
  - example: they are *not* designed for clusters

Key-Value Stores

- We've already worked with one of these: Berkeley DB
- 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

- Also store key/value pairs
- Unlike key-value stores, the value is *not* opaque.
  - it is a *document* containing semistructured data
  - it *can* be examined and used by the DBMS
- Queries:
  - can be based on the key (as in key/value stores)
  - more often, are based on the contents of the document
- Here again, there is support for sharding and replication.
  - the sharding can be based on values within the document

Column-Family Databases

- Google's BigTable and systems based on it
- To understand the motivation behind their design, consider one type of problem BigTable was designed to solve:
  - You want to store info about web pages!
  - For each URL, you want to store:
    - its contents
    - its language
    - for each other page that links to it, the *anchor text* associated with the link (i.e., the text that you click on)

Storing Web-Page Data in a Traditional Table

page URL	language	contents	anchor text from www.cnn.com	anchor from www.bu.edu	*one col per page*							
www.cnn.com	English	<html>…										…
www.bu.edu	English	<html>…										…
www.nytimes.com	English	<html>…		"news story"								…
www.lemonde.fr	French	<html>…	"French elections"									…
…												…
												…

- One row per web page
- Single columns for its language and contents
- *One column for the anchor text from each possible page,* since in theory any page could link to any other page!
- Leads to a huge *sparse* table – most cells are empty/unused.

Storing Web-Page Data in BigTable

- Rather than defining all possible columns, define a set of *column families* that each row should have.
  - example: a column family called *anchor* that replaces all of the separate anchor columns on the last slide
  - can also have column families that are like typical columns
- In a given row, only store columns with an actual value, representing them as (column key, value) pairs
  - column key = column family:qualifier
  - ex: `("anchor:www.bu.edu", "news story")`

column family (anchor) · *qualifier* (www.bu.edu) · *value* ("news story")

column key = column family:qualifier

Data Model for Column-Family Databases

- Different rows can have different schema.
  - i.e., different sets of column *keys*
  - (column key, value) pairs can be added or removed from a given row over time
- The set of column *families* in a given table rarely change.

Advantages of Column Families

- Gives an additional unit of data, beyond just a single row.
- Can be used for access controls.
  - restrict an application to only certain column families
- Column families can be divided up into *locality groups* that are stored together.
  - based on which column families are typically accessed together
  - advantage?

Aggregate Orientation

- Key-value, document, and column-family stores all lend themselves to an *aggregate-oriented* approach.
  - group together data that "belongs" together
    - i.e., that will tend to be accessed together

type of database	unit of aggregation
key-value store	the value part of the key/value pair
document database	a document
column-family store	a row (plus column-family sub-aggregates)

- Relational databases can't fully support aggregation.
  - no multi-valued attributes; focus on avoiding duplicated data
  - give each type of entity its own table, rather than grouping together entities/attributes that are accessed together

Aggregate Orientation (cont.)

- Example: data about customers
  - RDBMS: store a customer's address in only one table
    - use foreign keys in other tables that refer to the address
  - aggregate-oriented system: store the full customer address in several places:
    - customer aggregates
    - order aggregates
    - etc.
- Benefits of an aggregate-based approach in a NoSQL store:
  - provides a unit for sharding across the cluster
  - allows us to get related data without needing to access many different nodes

Schemalessness

- NoSQL systems are completely or mostly schemaless.
- Key-value stores: put whatever you like in the value
- Document databases: no restrictions on the schema used by the semistructured data inside each document.
  - although some do allow a schema, as with XML
- Column-family databases:
  - we do specify the column families in a given table
  - but no restrictions on the columns in a given column family and different rows can have different columns

Schemalessness (cont.)

- Advantages:
  - allows the types of data that are stored to evolve over time
  - makes it easier to handle nonuniform data
    - e.g., sparse tables
- Despite the fact that a schema is not required, programs that use the data need at least an *implicit* schema.
- Disadvantages of an implicit schema:
  - the DBMS can't enforce it
  - the DBMS can't use it to try to make accesses more efficient
  - different programs that access the same database can have conflicting notions of the schema

Example Document Database: MongoDB

- Mongo (from hu<u>mongo</u>us)
- Key features include:
  - replication for high availability
  - auto-sharding for scalability
  - documents are expressed using JSON/BSON
  - queries can be based on the contents of the documents
- Related documents are grouped together into *collections*.
  - what does this remind you of?

mongoDB

JSON

- JSON is an alternative data model for semistructured data.
  - JavaScript Object Notation
- Built on two key structures:
  - an *object*, which is a sequence of *fields* (name:value pairs)

```
{ id: "1000",
  name: "Sanders Theatre",
  capacity: 1000 }
```

  - an *array* of values

```
["123-456-7890", "222-222-2222", "333-333-3333"]
```

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

Example: JSON Object for a Person

```
{   firstName: "John",
    lastName: "Smith",
    age: 25,
    address: {
        streetAddress: "21 2nd Street",
        city: "New York",
        state: "NY",
        postalCode: "10021"
    },
    phoneNumbers: [
        {   type: "home",
            number: "212-555-1234"
        },
        {   type: "mobile",
            number: "646-555-4567"
        }
    ]
}
```

BSON

- MongoDB actually uses BSON.
    - a binary representation of JSON
    - BSON = marshalled JSON!
- BSON includes some additional types that are not part of JSON.
    - in particular, a type called ObjectID for unique id values.
- Each MongoDB document is a BSON object.

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 ObjectID

MongoDB Terminology

relational term	**MongoDB equivalent**
database	database
table	collection
row	document
attributes	fields (name:value pairs)
primary key	the _id field, which is the key associated with the document

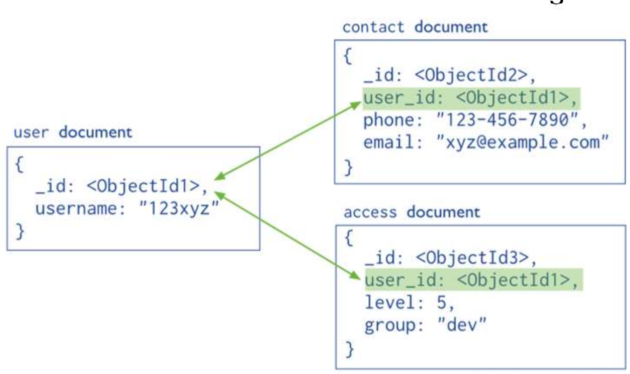
- Documents in a given collection typically have a similar purpose.
- However, no schema is enforced.
  - different documents in the same collection can have different fields

Data Modeling in MongoDB

- Need to determine how to map
  entities and relationships → collections of documents
- Could in theory give each type of entity:
  - its own (flexibly formatted) type of document
  - those documents would be stored in the same collection
- However, recall that NoSQL models allow for *aggregates* in which different types of entities are grouped together.
- Determining what the aggregates should look like involves deciding how we want to represent relationships.

Capturing Relationships in MongoDB

- Two options:
  1. store references to other documents using their `_id` values



source: docs.mongodb.org/manual/core/ data-model-design

  - where have we seen this before?

Capturing Relationships in MongoDB (cont.)

- Two options (cont.):
  2. embed documents within other documents

```
{
  _id: <ObjectId1>,
  username: "123xyz",
  contact: {
              phone: "123-456-7890",
              email: "xyz@example.com"
            },
  access: {
             level: 5,
             group: "dev"
           }
}
```

Embedded sub-document (contact)

Embedded sub-document (access)

source: docs.mongodb.org/manual/core/ data-model-design

- where have we seen this before?

Factors Relevant to Data Modeling

- A given MongoDB query can only access a single collection.
  - joins of documents are *not* supported
  - need to issue multiple requests
  - → group together data that would otherwise need to be joined

- Atomicity is only provided for operations on a single document (and its embedded subdocuments).
  - → group together data that needs to be updated as part of single logical operation (e.g., a balance transfer!)
  - → group together data items A and B if A's current value affects whether/how you update B

Factors Relevant to Data Modeling (cont.)

- If an update makes a document bigger than the space allocated for it on disk, it may need to be relocated.
  - slows down the update, and can cause disk fragmentation
  - MongoDB adds padding to documents to reduce the need for relocation

  → use references if embedded documents could lead to significant growth in the size of the document over time

Factors Relevant to Data Modeling

- Pluses and minuses of embedding (a partial list):
  - \+ need to make fewer requests for a given logical operation
  - \+ less network/disk I/O
  - \+ enables atomic updates
  - – duplication of data
  - – possibility for inconsistencies between different copies of duplicated data
  - – can lead documents to become very large, and to document relocation
- Pluses and minuses of using references:
  - take the opposite of the pluses and minuses of the above!
  - \+ allow you to capture more complicated relationships
    - ones that would be modelled using *graphs*

Data Model for the Movie Database

- Recall our movie database from PS 1.
  Person(id, name, dob, pob)
  Movie(id, name, year, rating, runtime, genre, earnings_rank)
  Oscar(movie_id, person_id, type, year)
  Actor(actor_id, movie_id)
  Director(director_id, movie_id)

- Three types of entities: movies, people, oscars

- Need to decide how we should capture the relationships
  - between movies and actors
  - between movies and directors
  - between Oscars and the associated people and movies

Data Model for the Movie Database (cont.)

- Assumptions about the relationships:
  - there are only one or two directors per movie
  - there are approx. five actors associated with each movie
  - the number of people associated with a given movie is fixed
  - each Oscar has exactly one associated movie
    and at most one associated person

- Assumptions about the queries:
  - Queries that involve both movies and people usually involve only the *names* of the people, not their other info.

    common: *Who directed Avatar?*
    common: *Which movies did Tom Hanks act in?*
    less common: *Which movies have actors from Boston?*
  - Queries that involve both Oscars and other entities usually involve only the *name(s)* of the person/movie.

Data Model for the Movie Database (cont.)

- Given our assumptions, we can take a hybrid approach that includes both references and embedding.
- Use three collections: movies, people, oscars
- Use references as follows:
  - in movie documents, include ids of the actors and directors
  - in oscar documents, include ids of the person and movie
- Whenever we refer to a person or movie, we also embed the associated entity's name.
  - allows us to satisfy common queries like *Who acted in…?*
- For less common queries that involve info. from multiple entities, use the references.

Data Model for the Movie Database (cont.)

- In addition, add two boolean fields to person documents:
  - hasActed, hasDirected
  - only include when true
  - allows us to find all actors/directors that meet criteria involving their pob/dob
- Note that most per-entity state appears only once, in the main document for that entity.
- The only duplication is of people/movie names and ids.

Sample Movie Document

```
{ _id: "0499549",
  name: "Avatar",
  year: 2009,
  rating: "PG-13",
  runtime: 162,
  genre: "AVYS",
  earnings_rank: 1,
  actors: [ { id: "0000244",
              name: "Sigourney Weaver" },
            { id: "0002332",
              name: "Stephen Lang" },
            { id: "0735442",
              name: "Michelle Rodriguez" },
            { id: "0757855",
              name: "Zoe Saldana" },
            { id: "0941777",
              name: "Sam Worthington" } ],
  directors: [ { id: "0000116",
                 name: "James Cameron" } ] }
```

Sample Person and Oscar Documents

```
{ _id: "0000059",
  name: "Laurence Olivier",
  dob: "1907-5-22",
  pob: "Dorking, Surrey, England, UK",
  hasActed: true,
  hasDirected: true
}

{ _id: ObjectId("528bf38ce6d3df97b49a0569"),
  year: 2013,
  type: "BEST-ACTOR",
  person: { id: "0000358",
            name: "Daniel Day-Lewis" },
  movie: { id: "0443272",
           name: "Lincoln" }
}
```

Queries in MongoDB

- Each query can only access a single collection of documents.
- Use a method called `db.collection.find()`

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

  - *collection* is the name of the collection
  - *<selection>* is an optional document that specifies one or more selection criteria
    - omitting it (i.e., using an empty document {}) selects all documents in the collection
  - *<projection>* is an optional document that specifies which fields should be returned
    - omitting it gets all fields in the document

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

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

Comparison with SQL

- Example: find the names and runtimes of all R-rated movies that were released in 2000.
- SQL:

```
SELECT name, runtime
FROM Movie
WHERE rating = 'R' and year = 2000;
```

- MongoDB:

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

Query Selection Criteria

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

- To find documents that match a set of field values, use a selection document consisting of those name/value pairs (see previous example).
- Operators for other types of comparisons:

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

- Example: find all movies with an earnings rank <= 200

```
db.movies.find({ earnings_rank: { $lte: 200 }})
```

- Note that the operator is the field name of a subdocument.

Query Selection Criteria (cont.)

- Logical operators: `$and, $or, $not, $nor`
  - take an *array* of selection subdocuments
  - example: find all movies rated R or PG-13:

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

  - example: find all movies *except* those rated R or PG-13 :

```
db.movies.find({ $nor: [ { rating: "R" },
                         { rating: "PG-13" }
                       ]
               })
```

Query Selection Criteria (cont.)

- To test for set-membership or lack thereof: `$in`, `$nin`
  - example: find all movies rated R or PG-13:

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

  - example: find all movies *except* those rated R or PG-13 :

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

  - ***note:*** `$in/$nin` is generally more efficient than `$or/$nor`

- To test for the presence/absence of a field: `$exists`
  - example: find all movies with an earnings rank:

```
db.movies.find({ earnings_rank: { $exists: true }})
```

  - example: find all movies *without* an earnings rank:

```
db.movies.find({ earnings_rank: { $exists: false }})
```

Logical AND

- You get an implicit logical AND by simply specifying a list of fields.
  - recall our previous example:

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

  - example: find all R-rated movies shorter than 90 minutes:

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

Logical AND (cont.)

- `$and` is needed if the subconditions involve the same field
  - can't have duplicate field names in a given document
- Example: find all Oscars given in the 1990s.
  - the following would ***not*** work:

```
db.oscars.find({ year: { $gte: 1990 },
                 year: { $lte: 1999 }
               })
```

  - one option that would work:

```
db.oscars.find({ $and: [ { year: { $gte: 1990 } },
                         { year: { $lte: 1999 } } ]
               })
```

  - another option: use an implicit AND on the operator subdocs:

```
db.oscars.find({ year: { $gte: 1990, $lte: 1999 }
               })
```

Pattern Matching

- Use a regular expression surrounded with //
  - example: find all people born in Boston

```
db.people.find({ pob: /*Boston,*/ })
```

  - `*` is a wildcard character that acts like `%` in SQL
- We get a `*` by default on either end of the expression, so we can do this instead:

```
db.people.find({ pob: /Boston,/ })
```

- To override the default * characters, use:
  ^ to require a match with the beginning of the value
  $ to require a match with the end of the value
  - `/Boston,/` would match "`South Boston, Mass`"
  - `/^Boston,/` would not, because the ^ indicates "`Boston`" must be at the start of the value
  - `/USA$/` requires "`USA`" to be at the end of the value

Query Practice Problem

- Recall our sample person document:

```
{ _id: "0000059",
  name: "Laurence Olivier",
  dob: "1907-5-22",
  pob: "Dorking, Surrey, England, UK",
  hasActed: true,
  hasDirected: true
}
```

- How could we find all directors born in the UK? (Select all that apply.)

A. `db.people.find({ pob: /UK$/, hasDirected: true })`

B.
```
db.people.find({ pob: /UK$/,
                 hasDirected: { $exists: true }})
```

C.
```
db.people.find({ pob: /UK/,
                 hasDirected: { $exists: true }})
```

D. `db.people.find({ $pob: /UK/, $hasDirected: true })`

Queries on Arrays/Subdocuments

- If a field has an array type

  `db.`*`collection`*`.find( { arrayField: val } )`

  finds all documents in which `val` is at least one of the elements in the array associated with `arrayField`

- Example: suppose that we stored a movie's genres as an array:

```
{ _id: "0317219", name: "Cars", year: 2006,
  rating: "G", runtime: 124, earnings_rank: 80,
  genre: ["N", "C", "F"], ...}
```

  - to find all animated movies – ones with a genre of "N":

    `db.movies.find( { genre: "N"} )`

- Given that we actually store the genres as a single string (e.g., "NCF"), how would we find animated movies?

Queries on Arrays/Subdocuments (cont.)

- Use dot notation to access fields within a subdocument, or within an array of subdocuments:
  - example: find all Oscars won by the movie *Gladiator:*

```
> db.oscars.find( { "movie.name": "Gladiator" } )

{ _id: <ObjectID1>, year: 2001,
  type: "BEST-PICTURE",
  movie: { id: "0172495",
           name: "Gladiator" }}
{ _id: <ObjectID2>, year: 2001,
  type: "BEST-ACTOR",
  movie: { id: "0172495",
           name: "Gladiator" },
  person: { id: "0000128",
            name: "Russell Crowe" }}
```

- ***Note***: When using dot notation, the field name must be surrounded by quotes.

Queries on Arrays/Subdocuments (cont.)

- example: find all movies in which Tom Hanks has acted:

```
> db.movies.find( { "actors.name": "Tom Hanks"} )

{ _id: "0107818", name: "Philadelphia", year: 1993,
  rating: "PG-13", runtime: 125, genre: "D"
  actors: [ { id: "0000158",
              name: "Tom Hanks" },
            { id: "0000243",
              name: "Denzel Washington" },
            ...
          ],
  directors: [ { id: "0001129",
                 name: "Jonathan Demme" } ]
}
{ _id: "0109830", name: "Forrest Gump", year: 1994,
  rating: "PG-13", runtime: 142, genre: "CD"
  actors: [ { id: "0000158",
              name: "Tom Hanks" },
            ...
```

Projections

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

- The projection document is a list of *fieldname:value* pairs:
  - a value of 1 indicates the field should be included
  - a value of 0 indicates the field should be excluded
- Recall our previous example:

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

- Example: find all info. about R-rated movies except their genres:

```
db.movies.find({ rating: "R" }, { genre: 0 })
```

Projections (cont.)

- The _id field is returned unless you explicitly exclude it.

```
> db.movies.find({ rating: "R", year: 2011 },
                 { name: 1 })
{ "_id" : "1411697", "name" : "The Hangover Part II" }
{ "_id" : "1478338", "name" : "Bridesmaids" }
{ "_id" : "1532503", "name" : "Beginners" }

> db.movies.find({ rating: "R", year: 2011 },
                 { name: 1, _id: 0 })
{ "name" : "The Hangover Part II" }
{ "name" : "Bridesmaids" }
{ "name" : "Beginners" }
```

- A given projection should either have:
  - all values of 1: specifying the fields to include
  - all values of 0: specifying the fields to exclude
  - one exception: specify fields to include, and exclude `_id`

Iterating Over the Results of a Query

- `db.`*`collection`*`.find()` returns a cursor that can be used to iterate over the results of a query
- In the MongoDB shell, if you don't assign the cursor to a variable, it will automatically be used to print up to 20 results.
  - if more than 20, use the command `it` to continue the iteration
- Another way to view all of the result documents:
  - assign the cursor to a variable:

    ```
    var cursor = db.movies.find({ year: 2000 })
    ```

  - use the following method call to print each result document in JSON:

    ```
    cursor.forEach(printjson)
    ```

Aggregation

- Recall the aggregate operators in SQL: `AVG()`, `SUM()`, etc.
- More generally, *aggregation* involves computing a result from a collection of data.
- MongoDB supports two approaches to aggregation:
  - single-purpose aggregation methods
  - an aggregation pipeline

Single-Purpose Aggregation Methods

- db.*collection*.count(<*selection*>)

  countDocuments is now the preferred name

  - returns the number of documents in the collection that satisfy the specified selection document
  - ex: 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 selection, get all distinct values of that field
  - ex: which actors have been in one or more of the top 10 grossing movies?

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

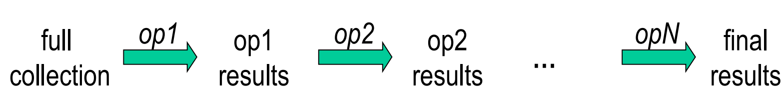
Aggregation Pipeline

- A more general-purpose and flexible approach to aggregation is to use a *pipeline* of aggregation operations.

- Each stage of the pipeline:
  - takes a set of documents as input
  - applies a *pipeline operator* to those documents, which transforms / filters / aggregates them in some way
  - produces a new set of documents as output

- db.*collection*.aggregate(

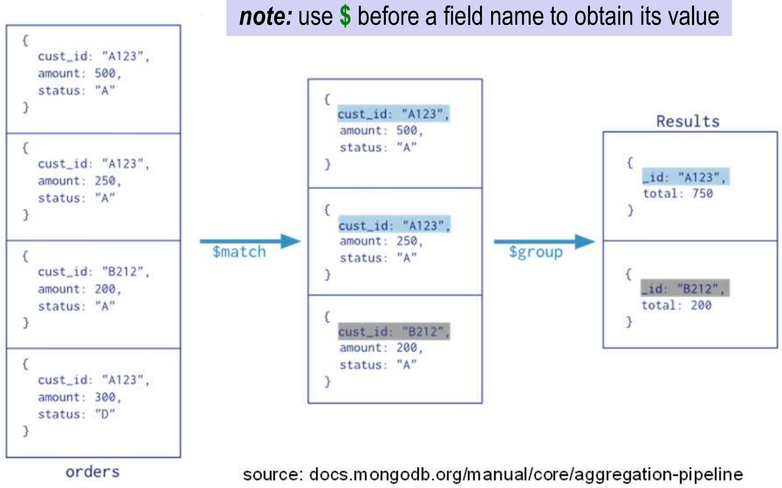
```
  { <pipeline-op1>: <pipeline-expression1> },
  { <pipeline-op2>: <pipeline-expression2> },
  ...,
  { <pipeline-opN>: <pipeline-expressionN> })
```



Aggregation Pipeline Example

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

note: use **$** before a field name to obtain its value



source: docs.mongodb.org/manual/core/aggregation-pipeline

Pipeline Operators

- `$project` – include, exclude, rename, or create fields
  - Example of a single-stage pipeline using $project:

```
db.people.aggregate(
  { $project: {
       name: 1,
       whereBorn: "$pob",
       yearBorn: { $substr: ["$dob", 0, 4] }
    }
  })
```

  - for each document in the people collection, extracts:
    - `name` (1 = include, as in earlier projection documents)
    - pob, which is renamed `whereBorn`
    - a new field called `yearBorn`, which is derived from the existing dob values (yyyy-m-d → yyyy)
    - the _id field, because we didn't exclude it
  - ***note:*** use **$** before a field name to obtain its value

Pipeline Operators (cont.)

- `$group` – like GROUP BY in SQL

  `$group: { _id: <field or fields to group by>,`
  `<computed-field-1>,`
  `..., <computed-field-N> }`

  - example: compute the number of movies with each rating

    ```
    db.movies.aggregate(
      { $group: { _id: "$rating",
                  numMovies: { $sum: 1 }
                } } )
    ```

    - `{ $sum: 1 }` is equivalent to COUNT(*) in SQL
      - for each document in a given subgroup, adds 1 to that subgroup's value of the computed field
    - can also sum values of a specific field (see earlier slide)
    - `$sum` is one example of an *accumulator*
    - others include: `$min`, `$max`, `$avg`, `$addToSet`

Pipeline Operators (cont.)

- `$match` – selects documents according to some criteria

  `$match: <selection>`

  where *<selection>* has identical syntax to the selection documents used by `db.`*`collection`*`.find()`

- `$unwind` – takes a document with an array of values and creates a separate document for each value in the array.
  - see the next example

Example of a Three-Stage Pipeline

```
db.movies.aggregate(
   { $match: { year: 2013 }},
   { $project: { _id: 0,
                 movie: "$name",
                 actor: "$actors.name" } },
   { $unwind: "$actor" }
)
```

- What does each stage do?
  - `$match`: select movies released in 2013
  - `$project`: for each such movie, create a document with:
    - no `_id` field
    - the `name` field of the movie, but renamed `movie`
    - the names of the actors (an array), as a field named `actor`
  - `$unwind`: turn each movie's document into a set of documents, one for each actor in the array of actors

Another Example: What does each stage do?

```
db.oscars.aggregate(
   { $match: { year: { $gte: 1980 } } },
   { $group: { _id: "$year", count: { $sum: 1 } } },
   { $match: { count: { $gt: 6 } } },
   { $project: { _id: 0, year: "$_id",
                 num_awards: "$count" } }  )
```

- first `$match`: select Oscars awarded in 1980 or later
- `$group`: take the Oscar docs selected by `$match` and:
  - create subgroups based on year (as specified by `_id` field)
  - for each subgroup, create a new doc with year as `_id` and a `count` field with the num. of Oscars from that year
- second `$match`: select docs for years with more than 6 Oscars
- `$project`: for each such year, create a document with:
  - no `_id` field
  - the `_id` field produced by `$group`, but renamed `year`
  - the `count` field produced by `$group`, renamed `num_awards`

More on Computing Aggregates

```
db.oscars.aggregate(
   { $match: { year: { $gte: 1980 } } },
   { $group: { _id: "$year", count: { $sum: 1 } } },
   { $match: { count: { $gt: 6 } } },
   { $project: { _id: 0, year: "$_id",
                 num_awards: "$count" } }  )
```

- The `$group` stage in the prior query computed a separate count for each of several subgroups.
- This is comparable to using an aggregate function with GROUP BY in SQL.

More on Computing Aggregates (cont.)

- What if we just want to compute a single count, average, etc.?
  - example: find the average runtime of all R-rated movies.
- In SQL, we would do something like this (with no GROUP BY):

```
SELECT AVG(runtime)
FROM Movie
WHERE rating = 'R';
```

- In MongoDB, we still need a `$group` stage, but we group on `null` in order to create a single group:

```
db.movies.aggregate(
    { $match: { rating: "R" } },
    { $group: { _id: null,
                avg_runtime: { $avg: "$runtime" }} },
    { $project: { _id: 0, avg_runtime: 1 } }
)
```

Two Additional Pipeline Operators

- `$sort` – sorts documents according to one of the fields

```
{ $sort: { field1_to_sort_on: sort_order1,
           field2_to_sort_on: sort_order2, …} }
```

  - for sort_order, use 1 for ascending
    -1 for descending

- `$limit` – include only the first n documents in a set of results

```
{ $limit: n }
```

- Example: Find the name and runtime of the movie with the longest runtime:

```
db.movies.aggregate( { $sort: { runtime: -1 } },
                     { $limit: 1 },
                     { $project: { _id: 0,
                                   name: 1,
                                   runtime: 1 } } )
```

  - note: if 2 or more movies are tied, will only get one of them

Recall: Sample Movie Document

```
{ _id: "0499549",
  name: "Avatar",
  year: 2009,
  rating: "PG-13",
  runtime: 162,
  genre: "AVYS",
  earnings_rank: 1,
  actors: [ { id: "0000244",
              name: "Sigourney Weaver" },
            { id: "0002332",
              name: "Stephen Lang" },
            { id: "0735442",
              name: "Michelle Rodriguez" },
            { id: "0757855",
              name: "Zoe Saldana" },
            { id: "0941777",
              name: "Sam Worthington" } ],
  directors: [ { id: "0000116",
                 name: "James Cameron" } ] }
```

Recall: Sample Person and Oscar Documents

```
{ _id: "0000059",
  name: "Laurence Olivier",
  dob: "1907-5-22",
  pob: "Dorking, Surrey, England, UK",
  hasActed: true,
  hasDirected: true
}

{ _id: ObjectId("528bf38ce6d3df97b49a0569"),
  year: 2013,
  type: "BEST-ACTOR",
  person: { id: "0000358",
            name: "Daniel Day-Lewis" },
  movie: { id: "0443272",
           name: "Lincoln" }
}
```

Extra Practice Writing Queries

1) Find the names of all people in the database who acted in *Avatar.*
   - SQL:

```
SELECT P.name
FROM Person P, Actor A, Movie M
WHERE P.id = A.actor_id
AND M.id = A.movie_id
AND M.name = 'Avatar';
```

   - MongoDB:

Extra Practice Writing Queries (cont.)

2) How many people in the database who were born in California have won an Oscar?

- SQL:

```
SELECT COUNT(DISTINCT P.id)
FROM Person P, Oscar O
WHERE P.id = O.person_id
AND P.pob LIKE '%,%California%';
```

- Can't easily answer this question using our MongoDB version of the database. Why not?