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Exploring the Aggregation Framework

Agenda

1. Analytics in MongoDB?

2. Aggregation Framework

3. Aggregation Framework in Action
   – US Census Data

1. Aggregation Framework Options

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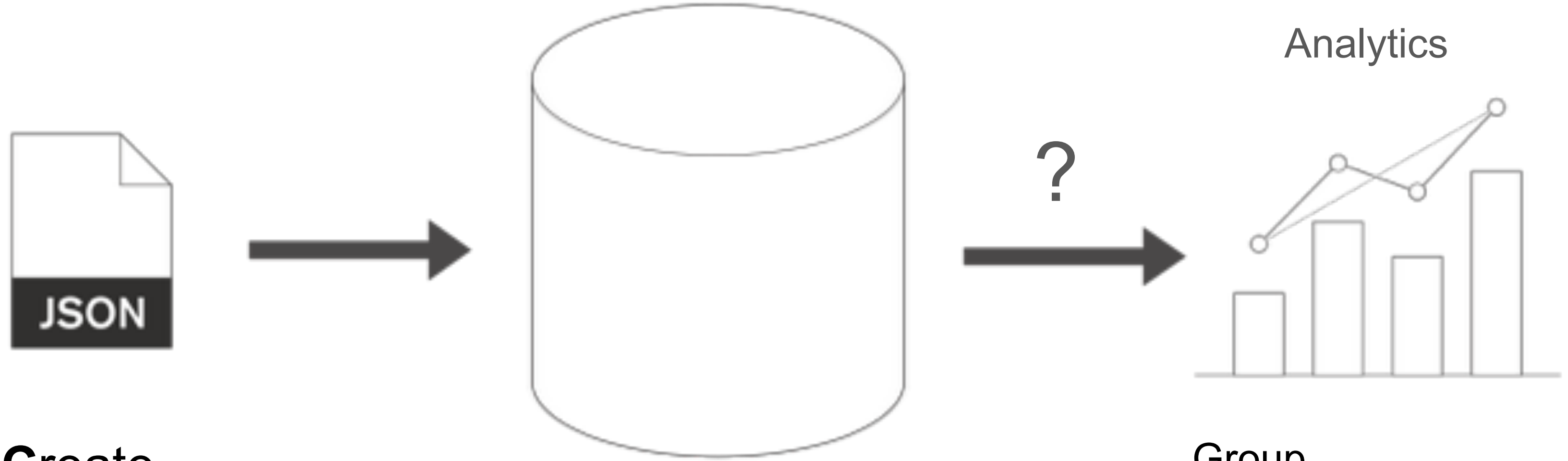
Analytics in MongoDB?



Create
Read
Update
Delete

Group
Count
Derive Values
Filter
Average
Sort

For Example: US Census Data

- Census data from 1990, 2000, 2010

- Question:

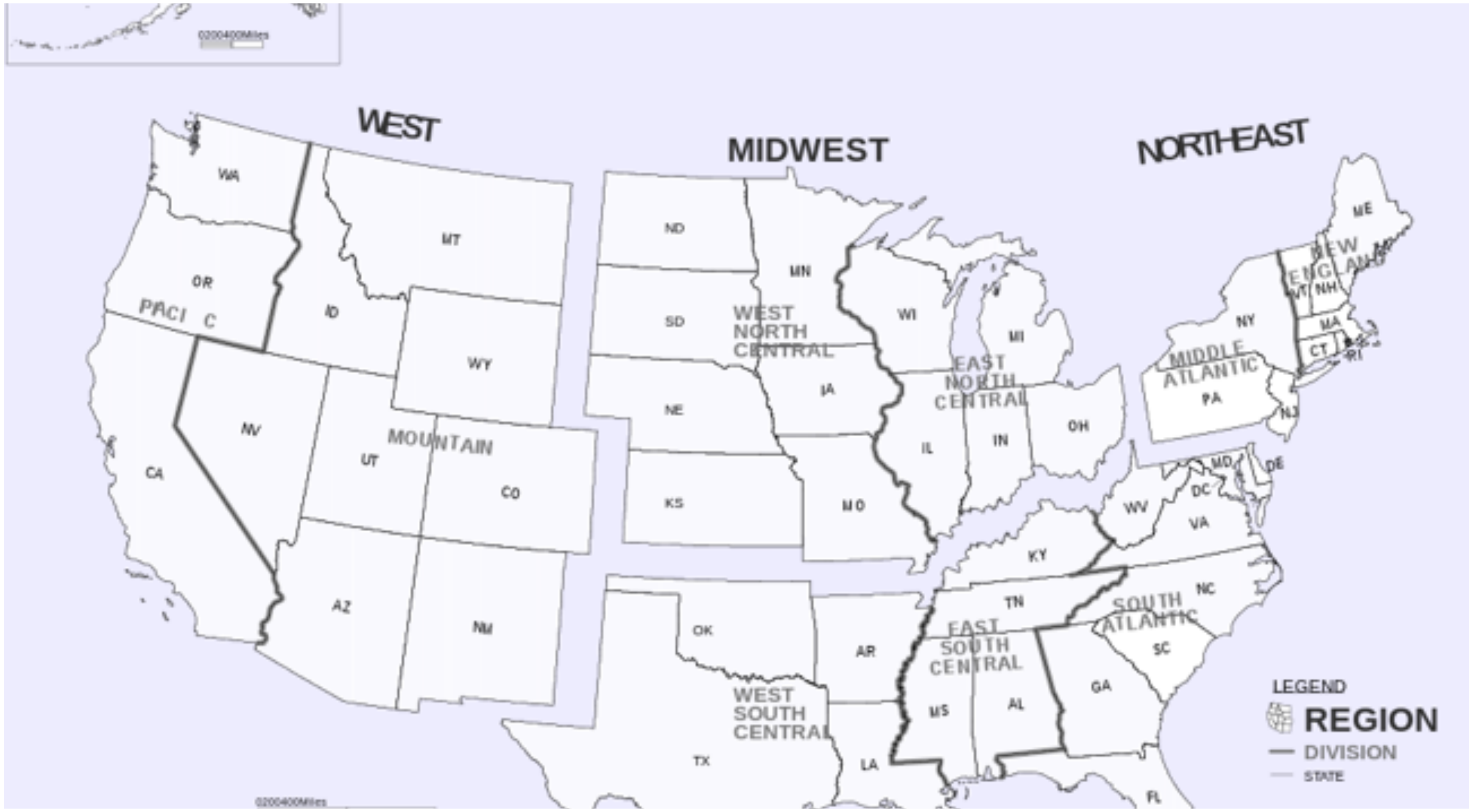
  Which US Division has the fastest growing population density?
  - We only want to include data for states with more than 1M people
  - We only want to include divisions larger than 100K square miles

Division = a group of US States

Population density = Area of division/# of people

Data is provided at the state level

US Regions and Divisions



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How would we solve this in SQL?

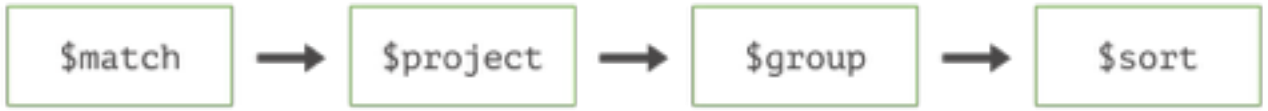
- SELECT GROUP BY HAVING

What About MongoDB?

The Aggregation Framework

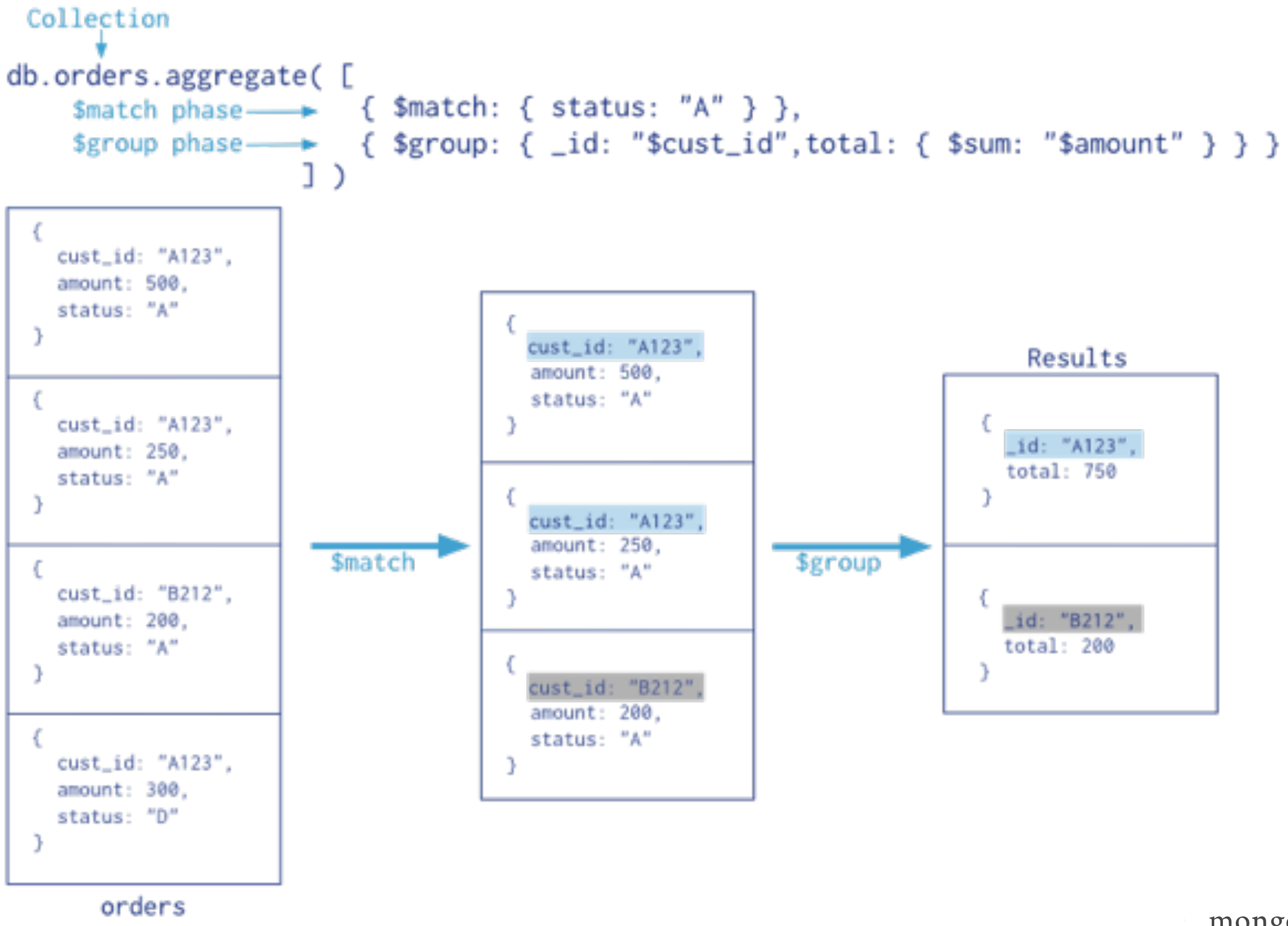
What is an Aggregation Pipeline?

- A Series of Document Transformations
  - Executed in stages
  - Original input is a collection
  - Output as a cursor or a collection



- Rich Library of Functions
  - Filter, compute, group, and summarize data
  - Output of one stage sent to input of next
  - Operations executed in sequential order

Aggregation Pipeline


Collection
$match phase
$group phase

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

{ cust_id: "A123", amount: 500, status: "A" }
{ cust_id: "A123", amount: 250, status: "A" }
{ cust_id: "B212", amount: 200, status: "A" }
{ cust_id: "A123", amount: 300, status: "D" }
orders
$match
{ cust_id: "A123", amount: 500, status: "A" }
{ cust_id: "A123", amount: 250, status: "A" }
{ cust_id: "B212", amount: 200, status: "A" }
$group
Results
{ _id: "A123", total: 750 }
{ _id: "B212", total: 200 }

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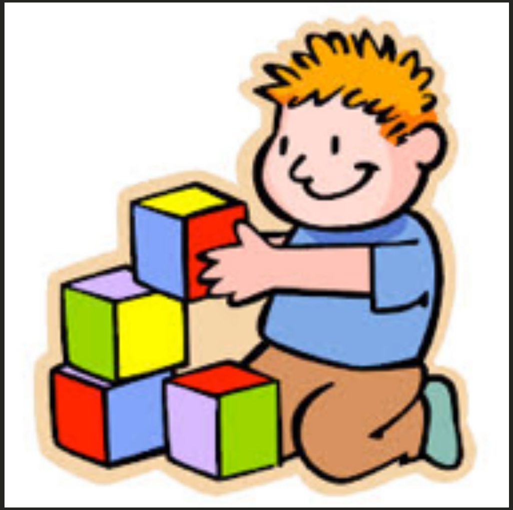
Pipeline Operators

- `$match`
  Filter documents
- `$project`
  Reshape documents
- `$group`
  Summarize documents
- `$unwind`
  Expand documents
- `$sort`
  Order documents
- `$limit/$skip`
  Paginate documents
- `$redact`
  Restrict documents
- `$geoNear`
  Proximity sort documents
- `$let,$map`
  Define variables

Aggregation Framework in Action (*let's play with the census data*)



MongoDB State Collection

- Document For Each State

- Name
- Region
- Division

- Census Data For 1990, 2000, 2010
  - Population
  - Housing Units
  - Occupied Housing Units

- Census Data is an array with three subdocuments

Document Model

```
{     "_id" : ObjectId("54e23c7b28099359f5661525"),
      "name" : "California",
      "region" : "West",
      "data" : [
        {"totalPop" : 33871648,
         "totalHouse" : 12214549,
         "occHouse" : 11502870,
         "year" : 2000},
        {"totalPop" : 37253956,
         "totalHouse" : 13680081,
         "occHouse" : 12577498,
         "year" : 2010},
        {"totalPop" : 29760021,
         "totalHouse" : 11182882,
         "occHouse" : 29008161,
         "year" : 1990}
       ],
       …
}
```

Total US Area

```
db.cData.aggregate([
    {"$group" : {"_id" : null,
                 "totalArea" : {$sum : "$areaM"},
                 "avgArea" : {$avg : "$areaM"}}}])
```

$group

- Group documents by value
  - Field reference, document, constant
  - Other output fields are computed
    - `$max, $min, $avg, $sum`
    - `$addToSet, $push`
    - `$first, $last`
  - Processes all data in memory by default

Area By Region

```
db.cData.aggregate([
    {"$group" : {"_id" : "$region",
                 "totalArea" : {$sum : "$areaM"},
                 "avgArea" : {$avg : "$areaM"},
                 "numStates" : {$sum : 1},
                 "states" : {$push : "$name"}}}
])
```

Calculating Average State Area By Region

```
{
  state: ”New York",
  areaM: 54554,
  region: “Northeast"
}
```

```
{
  state: ”New Jersey",
  areaM: 8722,
  region: “Northeast”
}
```

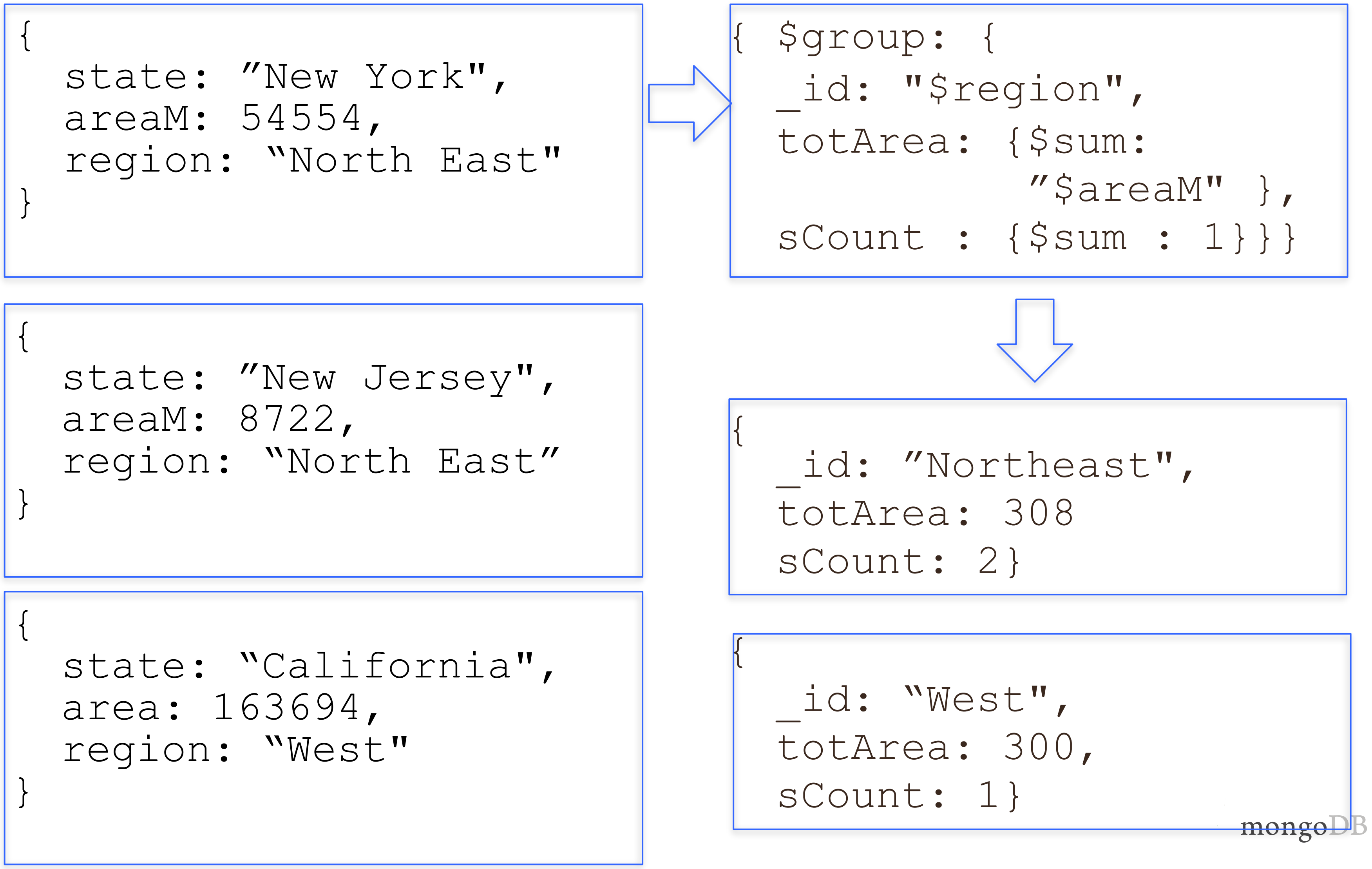
```
{
  state: “California",
  areaM: 163694,
  region: “West"
}
```

```
{ $group: {
  _id: "$region",
  avgArea: {$avg:
              ”$areaM" }
}}
```

```
{
  _id: ”Northeast",
  avgAreaM: 20146
}
```

```
{
  _id: “West",
  avgAreaM: 144096
}
```

Calculating Total Area and State Count



```
{
  state: ”New York",
  areaM: 54554,
  region: “North East"
}
```

```
{
  state: ”New Jersey",
  areaM: 8722,
  region: “North East”
}
```

```
{
  state: “California",
  area: 163694,
  region: “West"
}
```

```
{ $group: {
  _id: "$region",
  totArea: {$sum:
            ”$areaM" },
  sCount : {$sum : 1}}}
```

```
{
  _id: ”Northeast",
  totArea: 308
  sCount: 2}
```

```
{
  _id: “West",
  totArea: 300,
  sCount: 1}
```

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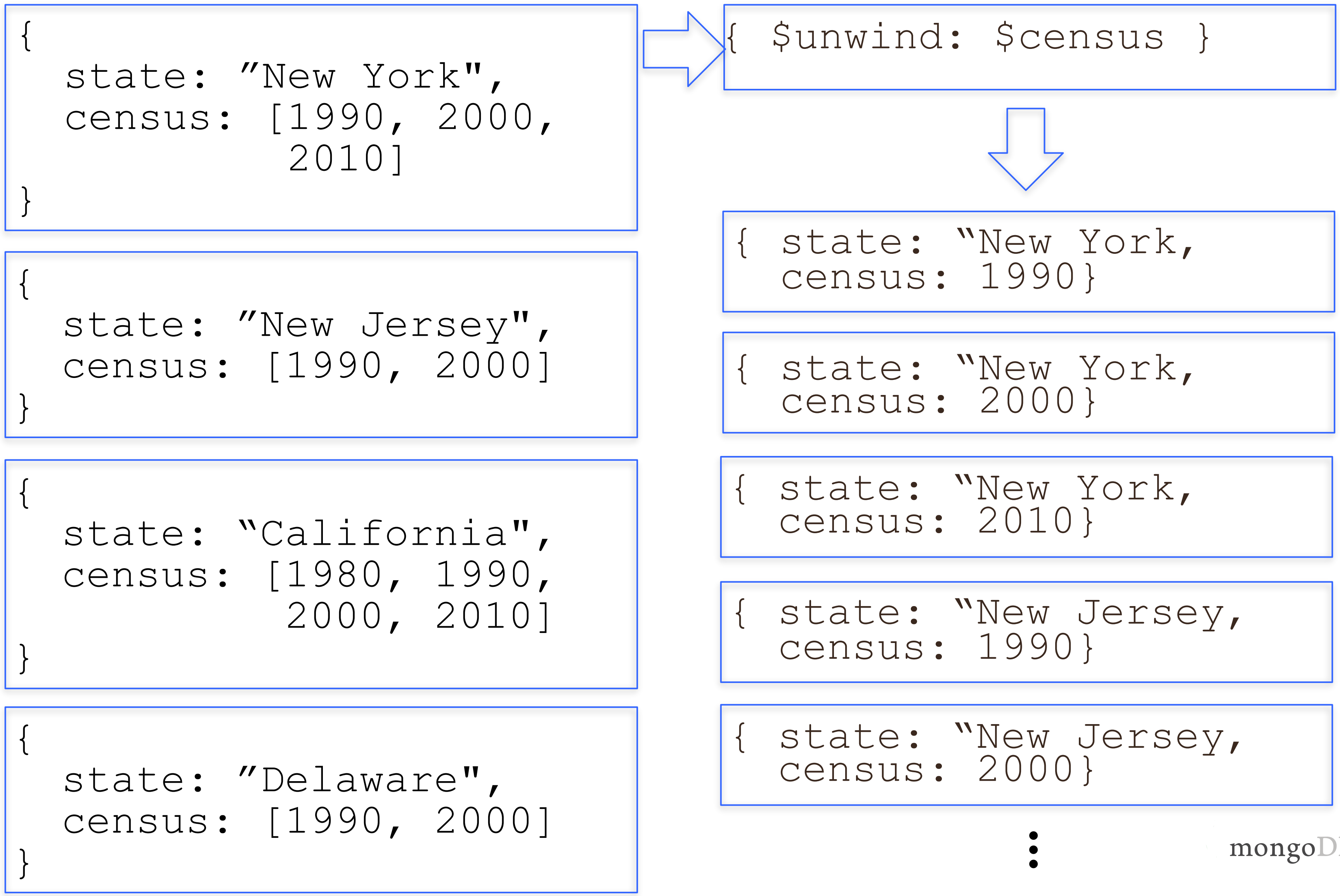
Total US Population By Year

```
db.cData.aggregate(
 [{$unwind : "$data"},
  {$group : {"_id" : "$data.year",
             "totalPop" : {$sum : "$data.totalPop"}}},
  {$sort : {"totalPop" : 1}}
])
```

$unwind

- Operate on an array field
  - Create documents from array elements
    - Array replaced by element value
    - Missing/empty fields → no output
    - Non-array fields → error
  - Pipe to $group to aggregate

$unwind



```
{
   state: ”New York",
   census: [1990, 2000,
               2010]
}
```

```
{
   state: ”New Jersey",
   census: [1990, 2000]
}
```

```
{
   state: “California",
   census: [1980, 1990,
               2000, 2010]
}
```

```
{
   state: ”Delaware",
   census: [1990, 2000]
}
```

```
{ $unwind: $census }
```

```
{  state: “New York,
   census: 1990}
```

```
{  state: “New York,
   census: 2000}
```

```
{  state: “New York,
   census: 2010}
```

```
{  state: “New Jersey,
   census: 1990}
```

```
{  state: “New Jersey,
   census: 2000}
```

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Southern State Population By Year

```
db.cData.aggregate(
   [{$match : {"region" : "South"}},
    {$unwind : "$data"},
    {$group : {"_id" : "$data.year"
                "totalPop” : {"$sum”
               "$data.totalPop"}}}])
```

Include example with compound group?

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$match

- Filter documents
  - Uses existing query syntax
  - No $where (server side Javascript)

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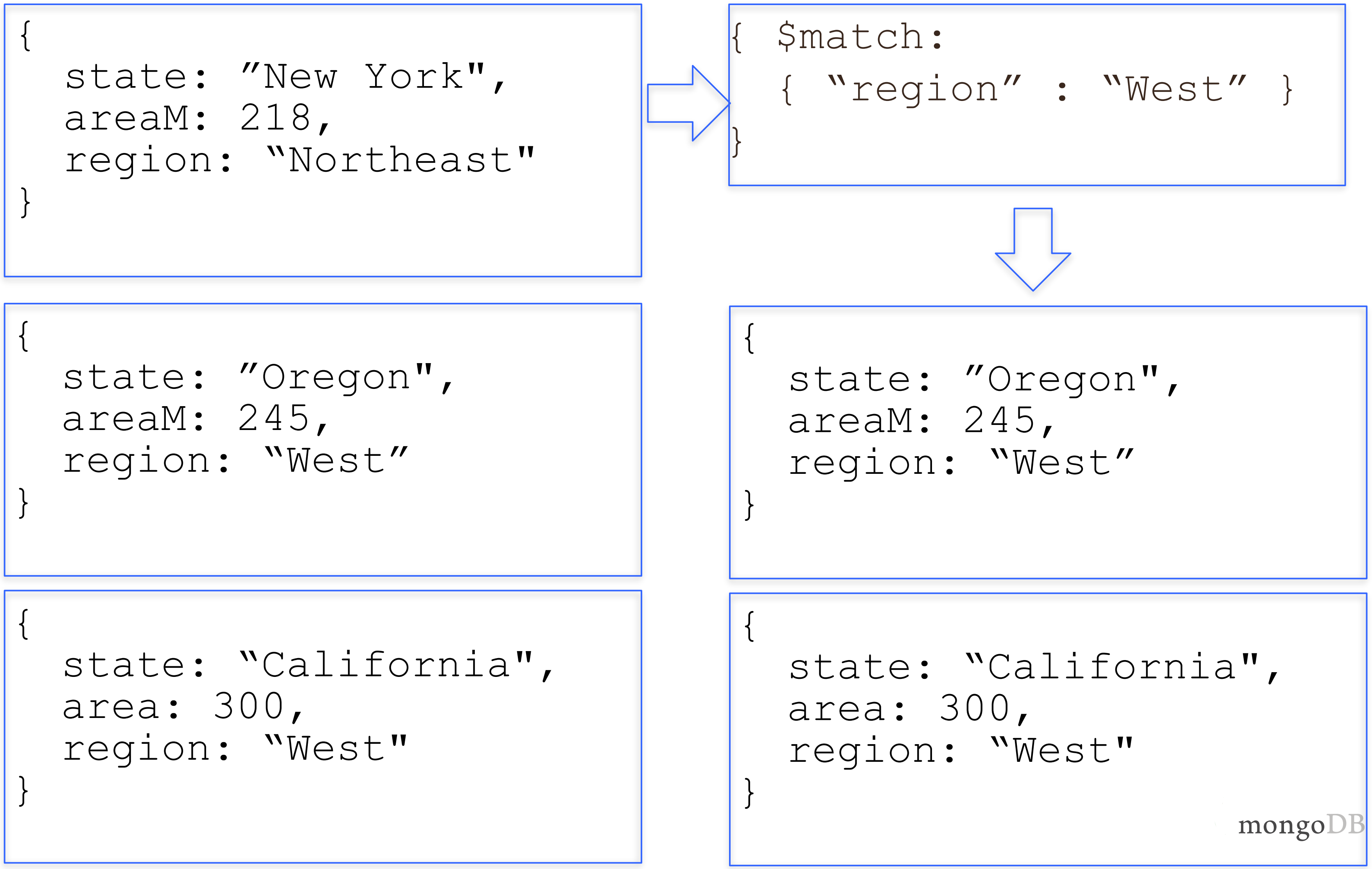
$match



```
{
  state: ”New York",
  areaM: 218,
  region: “Northeast"
}
```

```
{
  state: ”Oregon",
  areaM: 245,
  region: “West”
}
```

```
{
  state: “California",
  area: 300,
  region: “West"
}
```

```
{ $match:
  { “region” : “West” }
}
```

```
{
  state: ”Oregon",
  areaM: 245,
  region: “West”
}
```

```
{
  state: “California",
  area: 300,
  region: “West"
}
```

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Population Delta By State from 1990 to 2010

```
db.cData.aggregate(
  [{$unwind : "$data"},
   {$sort : {"data.year" : 1}},
{$group : {"_id" : "$name",
              "pop1990" : {"$first" : "$data.totalPop"},
              "pop2010" : {"$last" : "$data.totalPop"}}},
   {$project : {"_id" : 0,
                "name" : "$_id",
                "delta" : {"$subtract" :
                           ["$pop2010", "$pop1990"]},
                "pop1990" : 1,
                "pop2010” : 1}
   }]
)
```

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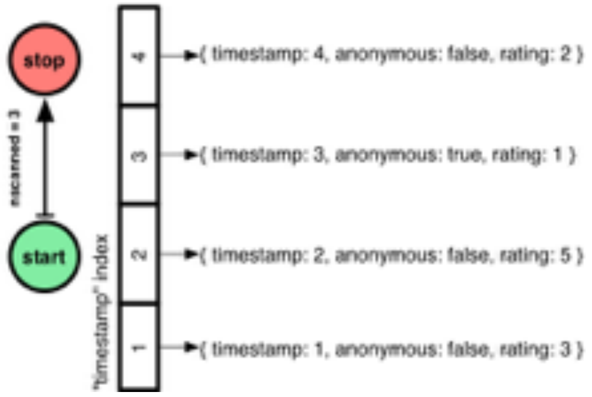
Population Delta By State from 1990 to 2010

```
db.cData.aggregate(
  [{$unwind : "$data"},
   {$sort : {"data.year" : 1}},
{$group : {"_id" : "$name",
             "pop1990" : {"$first" : "$data.totalPop"},
             "pop2010" : {"$last" : "$data.totalPop"}}},
   {$project : {"_id" : 0,
               "name" : "$_id",
               "delta" : {"$subtract" :
                          ["$pop2010", "$pop1990"]},
               "pop1990" : 1,
               "pop2010” : 1}
   }]
)
```

$sort, $limit, $skip

- Sort documents by one or more fields
  - Same order syntax as cursors
  - Waits for earlier pipeline operator to return
  - In-memory unless early and indexed



```
{ timestamp: 4, anonymous: false, rating: 2 }
{ timestamp: 3, anonymous: true, rating: 1 }
{ timestamp: 2, anonymous: false, rating: 5 }
{ timestamp: 1, anonymous: false, rating: 3 }
```

- Limit and skip follow cursor behavior

Population Delta By State from 1990 to 2010

```
db.cData.aggregate(
  [{$unwind : "$data"},
   {$sort : {"data.year" : 1}},
{$group : {"_id" : "$name",
              "pop1990" : {"$first" : "$data.totalPop"},
              "pop2010" : {"$last" : "$data.totalPop"}}},
   {$project : {"_id" : 0,
                "name" : "$_id",
                "delta" : {"$subtract" :
                           ["$pop2010", "$pop1990"]},
                "pop1990" : 1,
                "pop2010" : 1}
   }]
)
```

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$first, $last

- Collection operations like $push and $addToSet
- Must be used in $group
- $first and $last determined by document order
- Typically used with $sort to ensure ordering is known

Population Delta By State from 1990 to 2010

```
db.cData.aggregate(
  [{$unwind : "$data"},
   {$sort : {"data.year" : 1}},
{$group : {"_id" : "$name",
             "pop1990" : {"$first" : "$data.totalPop"},
             "pop2010" : {"$last" : "$data.totalPop"}}},
   {$project : {"_id" : 0,
               "name" : "$_id",
               "delta" : {"$subtract" :
                          ["$pop2010", "$pop1990"]},
               "pop1990" : 1,
               "pop2010" : 1}
   }]
)
```

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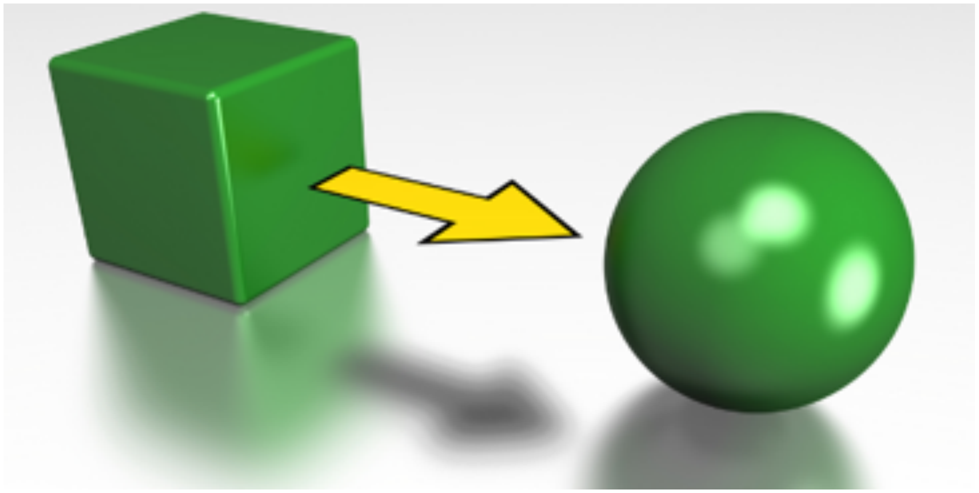
$project

- Reshape Documents
  - Include, exclude or rename fields
  - Compute field values
  - Create sub-document fields



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Including and Excluding Fields

```
{
   "_id" : "Virginia”,
   "pop1990" : 453588,
   "pop2010" : 3725789
}
```

```
{
   "_id" : "South Dakota",
   "pop1990" : 453588,
   "pop2010" : 3725789
}
```

```
{  $project:
   { “_id” : 0,
     “pop1990” : 1,
     “pop2010” : 1
}
```

```
{
   "pop1990" : 453588,
   "pop2010" : 3725789
}
```

```
{
   "pop1990" : 453588,
   "pop2010" : 3725789
}
```

Renaming and Computing Fields

```
{
   "_id" : "Virginia”,
   "pop1990" : 6187358,
   "pop2010" : 8001024
}
```

```
{
   "_id" : "South Dakota",
   "pop1990" : 696004,
   "pop2010" : 814180
}
```

```
{ $project:
  { “_id” : 0,
    “pop1990” : 0,
    “pop2010” : 0,
    “name” : “$_id”,
    "delta" :
      {"$subtract" :
        ["$pop2010",
         "$pop1990"]}}
}
```

```
{
  ”name" : “Virginia”,
  ”delta" : 1813666
}
```

```
{
  ”name" : “South Dakota”,
  ”delta" : 118176
}
```

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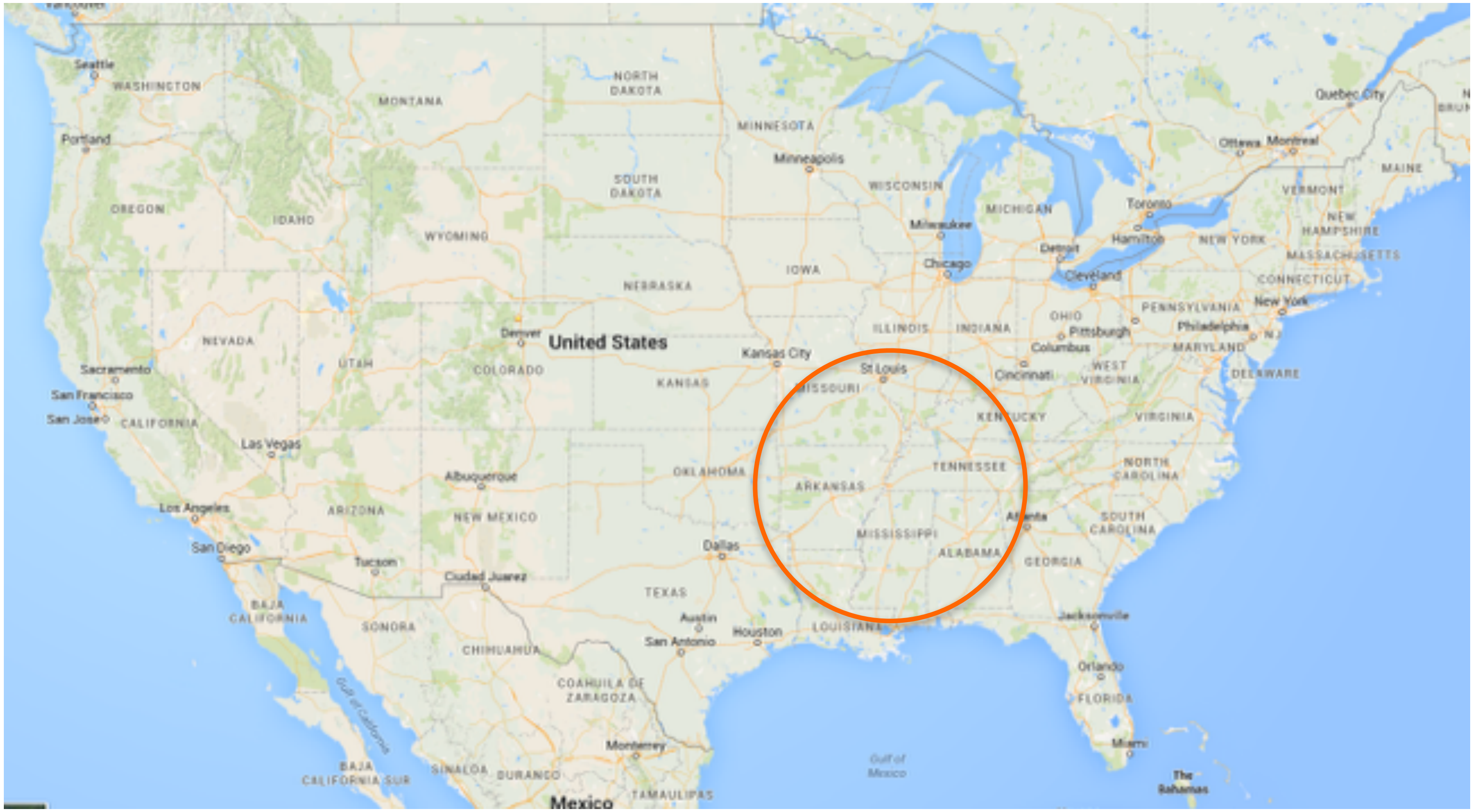
Compare number of people living within 500KM of Memphis, TN in 1990, 2000, 2010



Compare number of people living within 500KM of Memphis, TN in 1990, 2000, 2010

```
db.cData.aggregate([
  {$geoNear : {
      "near" : {"type" : "Point", "coordinates" : [90, 35]},
      “distanceField” : "dist.calculated",
      “maxDistance” : 500000,
      “includeLocs” : "dist.location",
      “spherical” : true  }},
  {$unwind : "$data"},
  {$group : {"_id" : "$data.year",
             "totalPop" : {"$sum" : "$data.totalPop"},
             "states" : {"$addToSet" : "$name"}}},
  {$sort : {"_id" : 1}}
])
```

$geoNear

- Order/Filter Documents by Location
  - Requires a geospatial index
  - Output includes physical distance
  - Must be first aggregation stage

$geoNear

```
{
   "_id" : "Virginia”,
   "pop1990" : 6187358,
   "pop2010" : 8001024,
   “center” :
      {“type” : “Point”,
       “coordinates” :
           [78.6, 37.5]}
}
```

```
{$geoNear : {
 "near”: {"type”: "Point",
          "coordinates”:
             [90, 35]},
 maxDistance : 500000,
 spherical : true  }}
```

```
{
   "_id" : ”Tennessee",
   "pop1990" : 4877185,
   "pop2010" : 6346105,
   “center” :
      {“type” : “Point”,
       “coordinates” :
           [86.6, 37.8]}
}
```

```
{
   "_id" : ”Tennessee",
   "pop1990" : 4877185,
   "pop2010" : 6346105,
   “center” :
      {“type” : “Point”,
       “coordinates” :
           [86.6, 37.8]}
}
```

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What if I want to save the results to a collection?

```
db.cData.aggregate([
  {$geoNear : {
      "near" : {"type" : "Point", "coordinates" : [90, 35]},
      “distanceField” : "dist.calculated",
      “maxDistance” : 500000,
      “includeLocs” : "dist.location",
      “spherical” : true  }},
  {$unwind : "$data"},
  {$group : {"_id" : "$data.year",
             "totalPop" : {"$sum" : "$data.totalPop"},
             "states" : {"$addToSet" : "$name"}}},
  {$sort : {"_id" : 1}},
  {$out : “peopleNearMemphis”}
])
```

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$out

```
db.cData.aggregate([<pipeline stages>,
                    {"$out" : "resultsCollection"}])
```

- Save aggregation results to a new collection
- New aggregation uses:
  - Transform documents - ETL

Back To The Original Question

- Which US Division has the fastest growing population density?
  - We only want to include states with more than 1M people
  - We only want to include divisions larger than 100K square miles

Division with Fastest Growing Pop Density

```
db.cData.aggregate(
  [{$match : {"data.totalPop" : {"$gt" : 1000000}}},
   {$unwind : "$data"},
   {$sort : {"data.year" : 1}},
   {$group : {"_id" : "$name",
              "pop1990" : {"$first" : "$data.totalPop"},
              "pop2010" : {"$last" : "$data.totalPop"},
                  "areaM" : {"$first" : "$areaM"},
              "division" : {"$first" : "$division"}}},
   {$group : {"_id" : "$division",
              "totalPop1990" : {"$sum" : "$pop1990"},
              "totalPop2010" : {"$sum" : "$pop2010"},
              "totalAreaM" : {"$sum" : "$areaM"}}},
   {$match : {"totalAreaM" : {"$gt" : 100000}}},
   {$project : {"_id" : 0,
                "division" : "$_id",
                "density1990" : {"$divide" : ["$totalPop1990", "$totalAreaM"]},
                "density2010" : {"$divide" : ["$totalPop2010", "$totalAreaM"]},
                "denDelta" : {"$subtract" : [{"$divide" : ["$totalPop2010",
                                                         "$totalAreaM"]},
                                             {"$divide" : ["$totalPop1990”,
                                                       "$totalAreaM"]}]},
                "totalAreaM" : 1,
                "totalPop1990" : 1,
                "totalPop2010" : 1}},
   {$sort : {"denDelta" : -1}}])
```

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Aggregate Options

Aggregate options

```
db.cData.aggregate([<pipeline stages>],
                    {‘explain’ : false
                     'allowDiskUse' : true,
                     'cursor' : {'batchSize' : 5}})
```

explain – similar to find().explain()

allowDiskUse – enable use of disk to store intermediate results

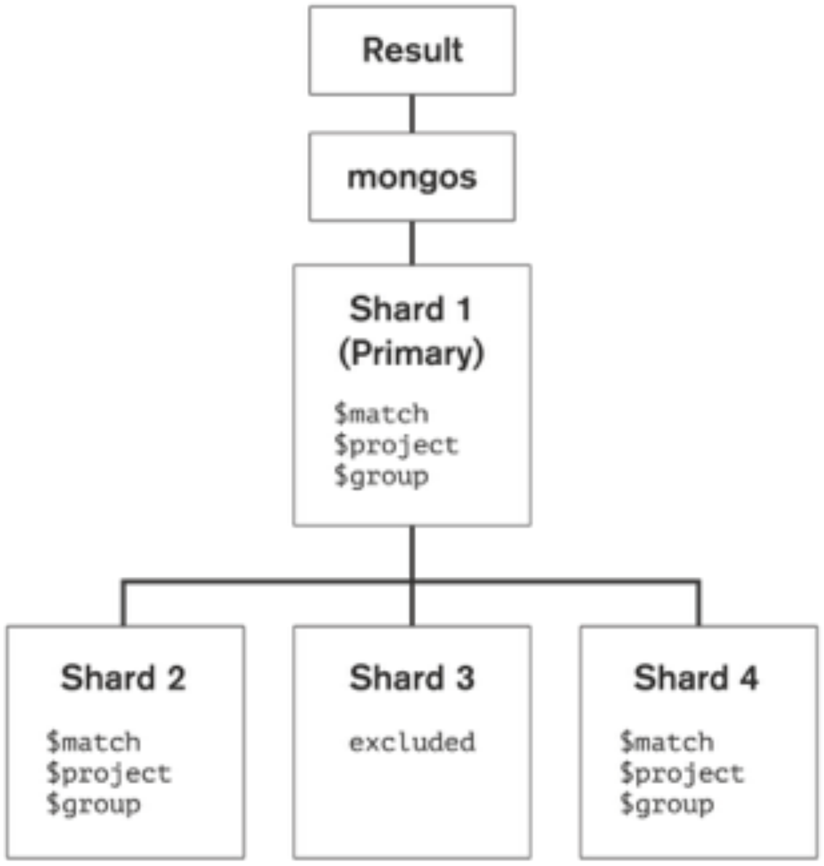
cursor – specify the size of the initial result

Aggregation and Sharding

Sharding

- Workload split between shards
  - Shards execute pipeline up to a point
  - Primary shard merges cursors and continues processing*
  - Use explain to analyze pipeline split
  - Early `$match` may excuse shards
  - Potential CPU and memory implications for primary shard host

*Prior to v2.6 second stage pipeline processing was done by mongos



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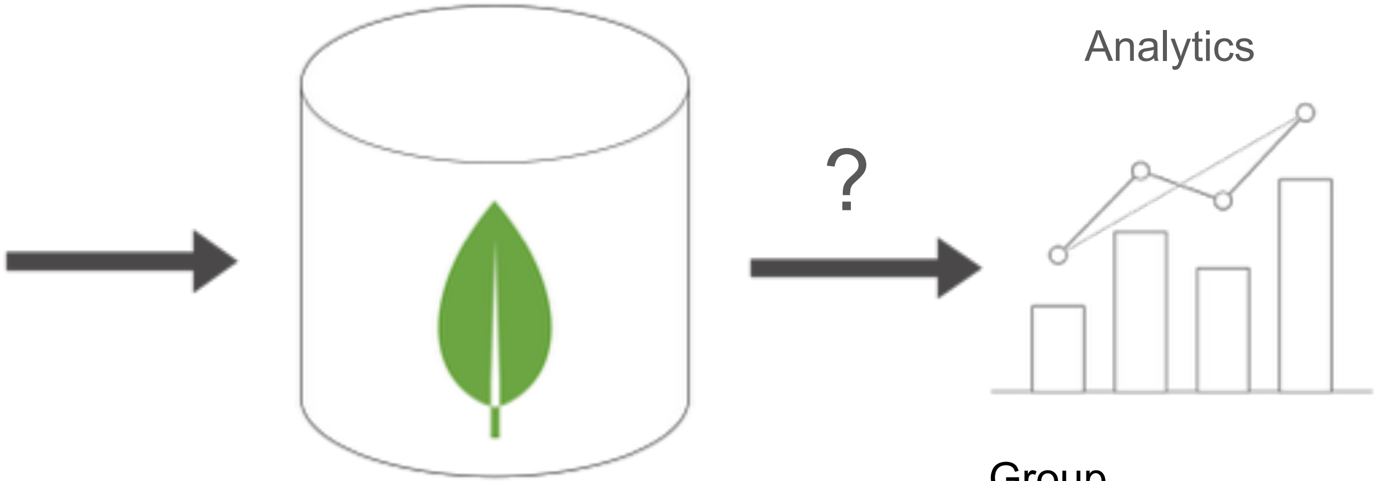
Summary

Analytics in MongoDB?

Create
Read
Update
Deletet



Group
Count
Derive Values
Filter
Average
Sort

YES!

Framework Use Cases

- Basic aggregation queries
- Ad-hoc reporting
- Real-time analytics
- Visualizing and reshaping data

Questions?

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