CS 4604: Introduction to Database Management Systems

NoSQL databases

Virginia Tech CS 4604 Sprint 2021

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Today’s Topics

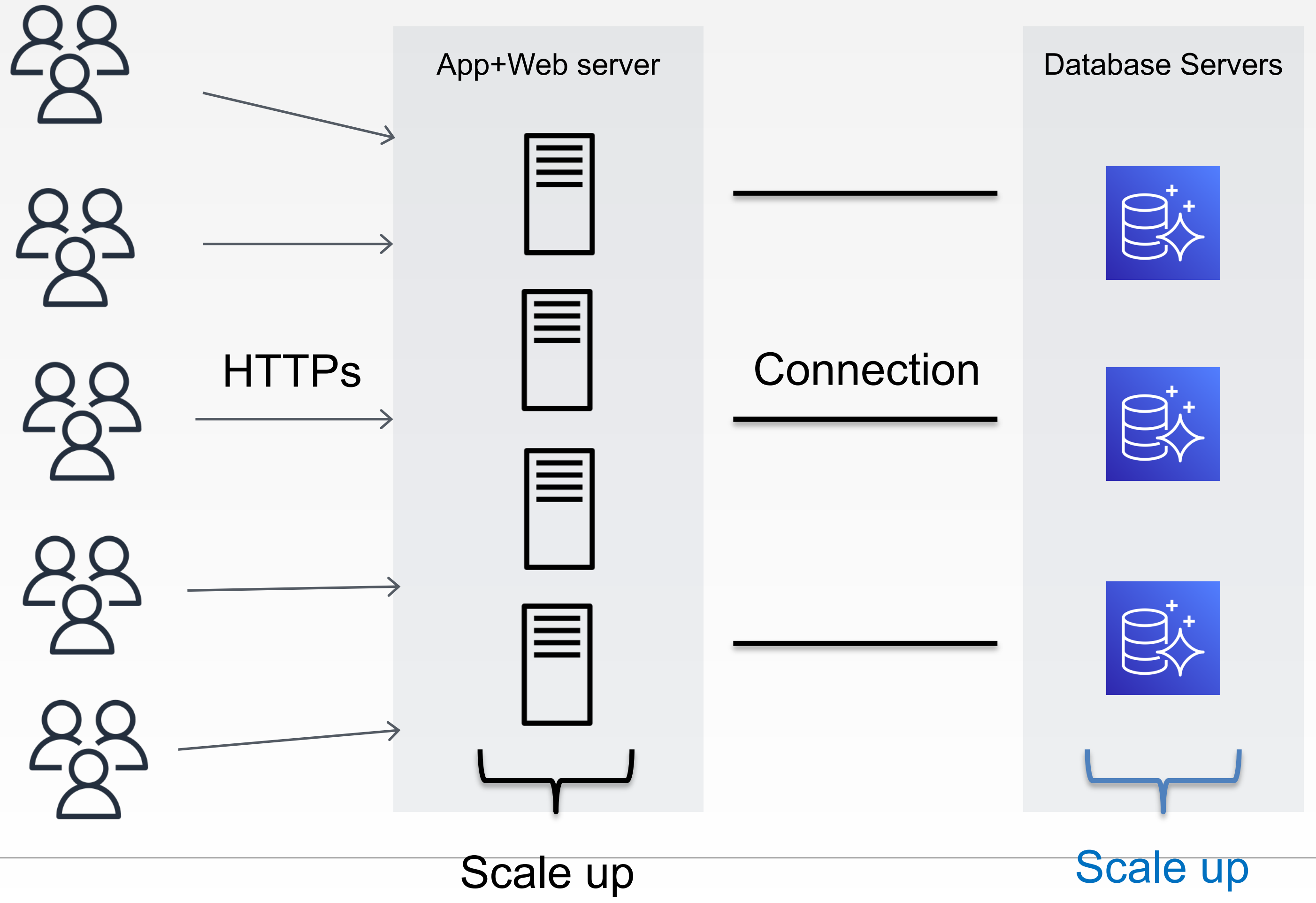
- NoSQL
  - Key-Value database
  - Document database

Two Classes of Relational Database App

- OLTP (Online Transaction Processing)
  - Queries are simple lookups: 0 or 1 join
    - E.g., find customer by ID and their orders
  - Many updates. E.g., insert order, update payment
  - Consistency is critical: we need transactions
- OLAP (Online Analytical Processing)
  - aka “Decision Support”
  - Queries have many joins, and group-by’s
    - E.g., sum revenues by store, product, clerk, date
  - No updates

NoSQL Motivation

- Originally motivated by Web 2.0 applications
  - E.g., Facebook, Amazon, Instagram, etc.
  - Startups need to scaleup from 10 to 10^7 clients quickly
- Needed: very large scale OLTP workloads
- Give up on consistency, give up OLAP
- NoSQL: reduce functionality
  - Simpler data model
  - Very restricted updates



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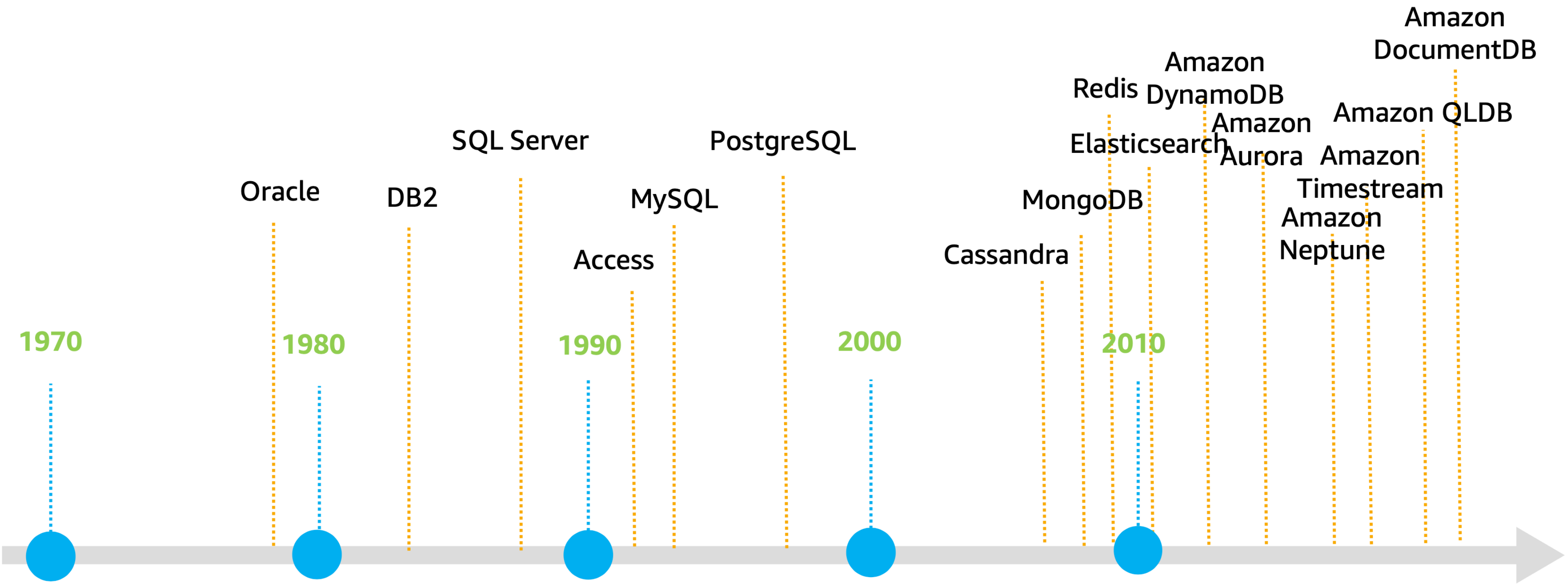
Replicating the Database

- Scale up through partitioning – “sharding”
  - Partition the database across many machines in a cluster
  - Database now fits in main memory
  - Queries spread across these machines
  - Can increase throughput
  - Easy for writes but reads become expensive!
- Scale up through replication
  - Create multiple copies of each database partition
  - Spread queries across these replicas
  - Can increase throughput and lower latency
  - Can also improve fault-tolerance
  - Easy for reads but writes become expensive!
- Consistency is much harder to enforce

Relational Model → NoSQL

- Relational DB: difficult to replicate/partition
  - Partition: we maybe forced to join across servers
  - Replication: local copy has inconsistent versions
  - Consistency is hard in both cases
- NoSQL: simplified data model
  - Given up on functionality
  - Application must now handle joins and consistency



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Relational Model vs NoSQL

- Relational DB (ACID)
  - **A**tomicity
  - **C**onsistency
  - **I**solation
  - **D**urability
- NoSQL (BASE)
  - **B**asic **A**vailability
    - Application must handle partial failures itself
  - **S**oft State
    - DB state can change even without inputs
  - **E**ventually Consistency
    - DB will “eventually” become consistent

What’s NoSQL?

- The misleading term “NoSQL” is short for “Not Only SQL”.
- Non-relational, schema-free, non-(quite)-ACID – More on ACID transactions later in class
- Horizontally scalable, distributed, easy replication support
- Simple API

NoSQLs

Key value	Document	In-memory	Graph	Search	Time series	Ledger
Low-latency, key lookups with high throughput and fast ingestion of data	Indexing and storing documents with support for query on any attribute	Microseconds latency, key-based queries, and specialized data structures	Creating and navigating data relations easily and quickly	Indexing and searching semistructured logs and data	Collect, store, and process data sequenced by time	Complete, immutable, and verifiable history of all changes to application data
Real-time bidding, shopping cart, social	Content management, personalization, mobile	Leaderboards, real-time analytics, caching	Fraud detection, social networking, recommendation engine	Product catalog, help, and FAQs, full text	IoT applications, event tracking	Systems of record, supply chain, healthcare, registrations, financial

Key-value (K-V) Stores

- **Data model**: (key, value) pairs
  - Key = string/integer, unique for the entire data
  - Value = can be anything (very complex object)
- **Operations**
  - get(key), put(key, value)
  - Operations on value not supported
- **Distribution / Partitioning** – w/ hash function
  - No replication: key k is stored at server h(k)
  - Multi way-way replication: e.g., key k stored at h1(k), h2(k), h3(k)
- Amazon DynamoDB, Voldemort, Memcached, …

Key-Value Stores Internals

- Partitioning:
  - Use a hash function h
  - Store every (key, value) pair on server h(key)
- Replication:
  - Store each key on (say) three servers
  - On update, propagate change to the other servers; ***eventual consistency***
  - Issue: when an app reads one replica, it may be stale
- Usually: combine partitioning + replication

Amazon DynamoDB Demo

Document Database

- Designed to store and query data as JSON-like documents
- Flexible schema and indexing, powerful ad hoc queries, and analytics over collections of documents
- Enable developers to store and query data in a database by using the same document-model format they use in their application code
- The document model works well with use cases like
  - Catalogs, user profiles, and content management systems where each document is unique and evolves over time

Document Database

- MongoDB
- Amazon DocumentDB (with MongoDB compatibility)
- SimpleDB
- CouchDB
- …

Motivation

- In Key-Value stores, the Value is often a very complex object
  - Key = ‘2010/7/1’, Value = [all flights that date]
- Better: *value* to be structured data
  - JSON or XML or Protobuf
  - Called a “document” but it’s just data

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"] },

- JSON data model
- Internally stored as BSON = Binary JSON
- Client libraries can directly operate on this natively

MongoDB Data Model

- Can use JSON schema validation
  - Some integrity checks, field typing and ensuring the presence of certain fields
- 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

```
_id: ObjectId("573a13adf29313caabd2bf71")
plot: "After being held captive in an Afghan cave, an industrialist creates a..."
> genres: Array
runtime: 126
metacritic: 79
rated: "PG-13"
v cast: Array
    0: "Robert Downey Jr."
    1: "Terrence Howard"
    2: "Jeff Bridges"
    3: "Gwyneth Paltrow"
poster: "https://m.media-amazon.com/images/M/MV5BMTczNTI2ODUwOF5BMl5BanBnXkFtZT..."
title: "Iron Man"
fullplot: "Tony Stark. Genius, billionaire, playboy, philanthropist. Son of legen..."
> languages: Array
released: 2008-05-02T00:00:00.000+00:00
> directors: Array
> writers: Array
v awards: Object
    wins: 20
    nominations: 51
    text: "Nominated for 2 Oscars. Another 18 wins & 51 nominations."
lastupdated: "2015-08-23 00:04:50"
year: 2008
v imdb: Object
    rating: 7.9
    votes: 615059
    id: 371746
> countries: Array
type: "movie"
```

JSON - Overview

- JavaScript Object Notation = lightweight text- based open standard designed for human- readable data interchange. Interfaces in C, C++, Java, Python, Perl, etc.
- The filename extension is .json
- Semi structured data
  - Does not have the same level of organization and predictability of structured data
  - The data does not reside in fixed fields or records, but does contain elements that can separate the data into various hierarchies

Nested JSON Object Example

```
{
  "name":"John",
  "age":30,
  "cars": {
    "car1":"Ford",
    "car2":"BMW",
    "car3":"Fiat"
  }
}
```

JSON vs Relational

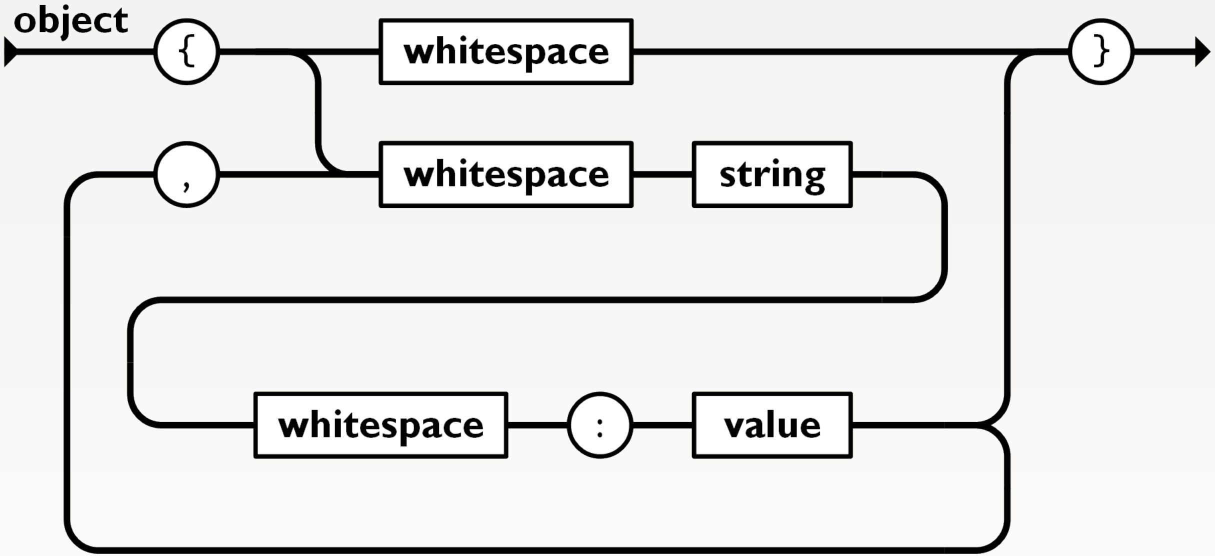
- Relational data model
  - Rigid flat structure (tables)
  - Schema must be **fixed** in advanced
  - Binary representation: good for performance, bad for exchange
  - Query language based on **Relational Algebra**
- Semi-structured data model / JSON
  - Flexible, nested structure (trees)
  - Does not require predefined schema ("self-describing”)
  - Text representation: good for exchange, bad for performance
  - Most common use: Language API; query languages emerging

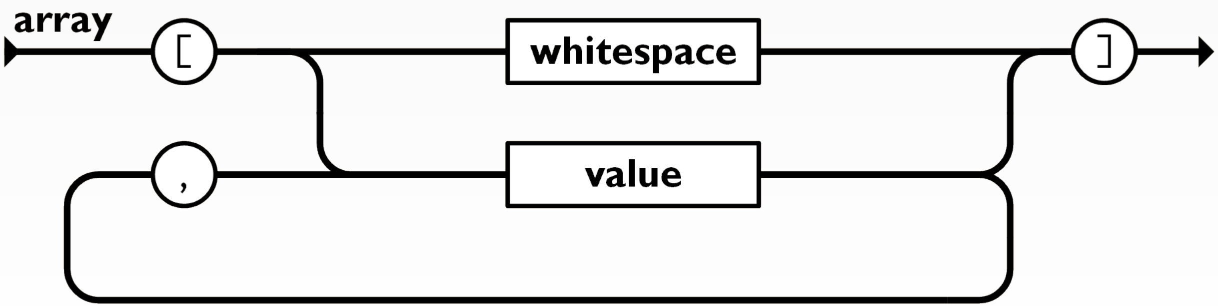
JSON Types

- Primitive: number, string, Boolean, null
- Object: collection of name-value pairs:
  - {“name1”: value1, “name2”: value2, ...}
  - “name” is also called a “key”
- Array: *ordered* list of values:
  - [obj1, obj2, obj3, ...]

JSON Syntax

https://www.json.org/





Avoid Using Duplicate Keys

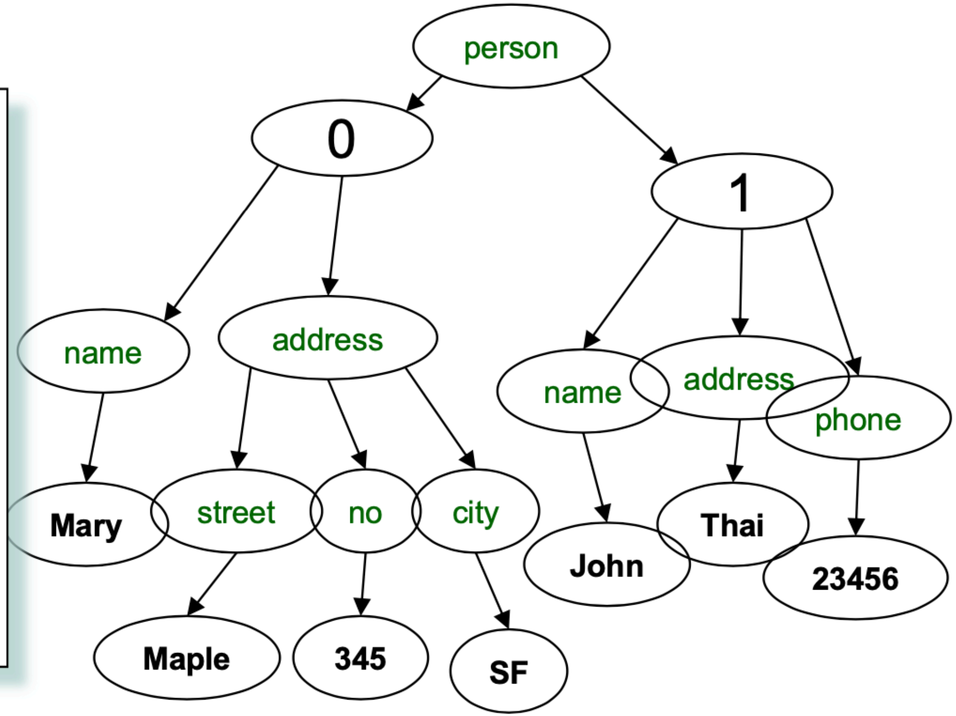
- The standard allows them, but many implementations don't

```
{"id":"07",
    "title": "Databases",
    "author": "Garcia",
    "author": "Ullman",
    "author": "Widom"
}
```

```
{"id":"07",
    "title": "Databases",
    "author": ["Garcia",
               "Ullman",
               "Widom"]
}
```

JSON Semantics: Tree presentation

```
{"person":
    [ {"name": "Mary",
      "address":
        {"street":"Maple",
         "no":345,
         "city": "SF"}},
     {"name": "John",
      "address": "Thailand",
      "phone":2345678}}
    ]
}
```



Intro to Semi-structured Data

- JSON is self-describing
- Schema elements become part of the data
  - Relational schema: person(name, phone)
  - In JSON “person”, “name”, “phone”
    are part of the data, and are repeated many times
- JSON is more flexible
  - Schema can change per tuple

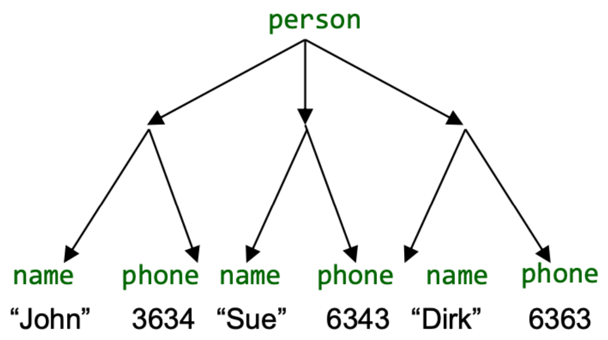
Storing JSON in RDBMS

- Using JSON as a data type provided by RDBMSs
  - Declare a column that contains either json or jsonb (binary)
  - CREATE TABLE people (person json) [or jsonb for binary]
- Some databases support
  - E.g. MySQL:
    - SELECT * FROM students
      WHERE JSON_EXTRACT(student, '$.age') = 12;
- Translate JSON documents into relations

Mapping Relational Data to JSON

Person

name	phone
John	3634
Sue	6343
Dirk	6363




```
{“person”: [
   {“name”: “John”, “phone”:3634},
   {“name”: “Sue”,  “phone”:6343},
    {“name”: “Dirk”, “phone”:6383}
   ]
}
```

Mapping Relational Data to JSON

May inline multiple relations based on foreign keys

Person

name	phone
John	3634
Sue	6343

Orders

personName	date	product
John	2002	Gizmo
John	2004	Gadget
Sue	2002	Gadget

```
{“Person”:
 [{"name": "John",
   "phone":3646,
   "Orders":[
    {"date":2002,"product":"Gizmo"},
    {“date”:2004,"product":"Gadget"}
   ]
  },
  {"name": "Sue",
   "phone":6343,
   "Orders":[
   {"date":2002,"product":"Gadget"}
   ]
  }
 ]
}
```

Mapping Relational Data to JSON

Many-many relationships are more difficult to represent

Person

name	phone
John	3634
Sue	6343

Product

prodName	price
Gizmo	19.99
Phone	29.99
Gadget	9.99

Orders

personName	date	product
John	2002	Gizmo
John	2004	Gadget
Sue	2002	Gadget

Options for the JSON file:

- 3 flat relations: Person,Orders,Product
- Person→Orders→Products products are duplicated
- Product→Orders→Person persons are duplicated

Mapping Semi-structured Data to Relations

- Missing attributes:

```
{"person":
    [{"name":"John", "phone":1234},
     {"name":"Joe"}]
}
```

no phone !

- Could represent in a table with nulls

name	phone
John	1234
Joe	NULL

Mapping Semi-structured Data to Relations

- Repeated attributes

```
{“person”:
     [{“name”:”John”, “phone”:1234},
      {“name”:”Mary”, “phone”:[1234,5678]}]
}
```

Two phones !

- Impossible in one table:

name	phone	
Mary	2345	3456

???

Mapping Semi-structured Data to Relations

- Attributes with different types in different objects

```
{"person":
     [{"name":"Sue", "phone":3456},
      {"name":{"first":"John", "last":"Smith"},"phone":2345}
     ]
}
```

Structured name !

- Nested collections
- Heterogeneous collections

- These are difficult to represent in the relational model

Why Semi-Structured Data?

- Semi-structured data works well as *data exchange formats*
  - i.e., exchanging data between different apps
  - Examples: XML, JSON, Protobuf (protocol buffers)
- Systems use them as a data model for DBs:
  - SQL Server supports for XML-valued relations
  - CouchBase, MongoDB, Snowflake: JSON
  - Dremel (BigQuery): Protobuf

Query Languages for Semi-Structured Data

- XML: XPath, XQuery (see textbook Ch 27)
  - Supported inside many RDBMS (SQL Server, DB2, Oracle)
  - Several standalone XPath/XQuery engines
- Protobuf: SQL-ish language (Dremel) used internally by google, and externally in BigQuery
- JSON:
  - CouchBase: N1QL
  - AsterixDB: SQL++ (based on SQL)
  - MongoDB: has a pattern-based language
  - JSONiq: http://www.jsoniq.org/

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 the instock field
    - Applies only when instock is a nested doc or an array of nested docs
      - If instock is a nested doc, 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"e → 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

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.collection.find(<predicate>, optional <projection>)
  - find({title: "Iron Man"})
    - all documents with title is “Iron Man”
  - find({qty:{$gte:50}})
    - all documents with qty >= 50
  - find({beds : 6, qty:{$gte:50}})
    - all documents that satisfy both
  - find({$or:[{beds : 6},{qty:{$lt:30}}]})
    - all documents that satisfy either

Retrieval Queries: Nested Documents

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

Retrieval Queries: Arrays

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

Retrieval Queries: Arrays of Documents

- db.collection.find(<predicate>, optional <projection>)
- find({ instock: { loc: "A", qty: 5 }})
  - Exact match of document [like nested doc/atomic array case]
- find({ "instock.qty": { $gte : 20 }})
  - One nested doc has >= 20
- find({ "instock.0.qty": { $gte : 20 } })
  - First nested doc has >= 20
- find({ "instock": { $elemMatch: { qty: { $gt: 10, $lte: 20 } } } })
  - One doc has 20 >= qty >10
- find({ "instock.qty": { $gt: 10, $lte: 20 } })
  - One doc has 20 >= qty, another has qty>10

Retrieval Queries Template: Projection

- 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

```
MongoDB> db.movies.find({cast: "Rebecca Ferguson", cast: "Tom Cruise"},
{title: 1})
{ "_id" : ObjectId("573a1397f29313caabce8ce7"), "title" : "Risky Business" }
{ "_id" : ObjectId("573a1398f29313caabce9932"), "title" : "Legend" }
{ "_id" : ObjectId("573a1398f29313caabcea315"), "title" : "Top Gun" }
```

Retrieval Queries : Addendum

- 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 })

Retrieval Queries: Summary

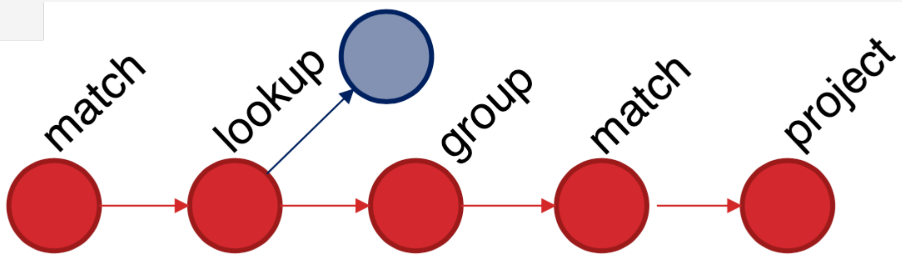
find() = SELECT <projection>
FROM Collection
WHERE <predicate>
limit() = LIMIT
sort() = ORDER BY

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

FROM
WHERE
SELECT
ORDER BY
LIMIT

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:

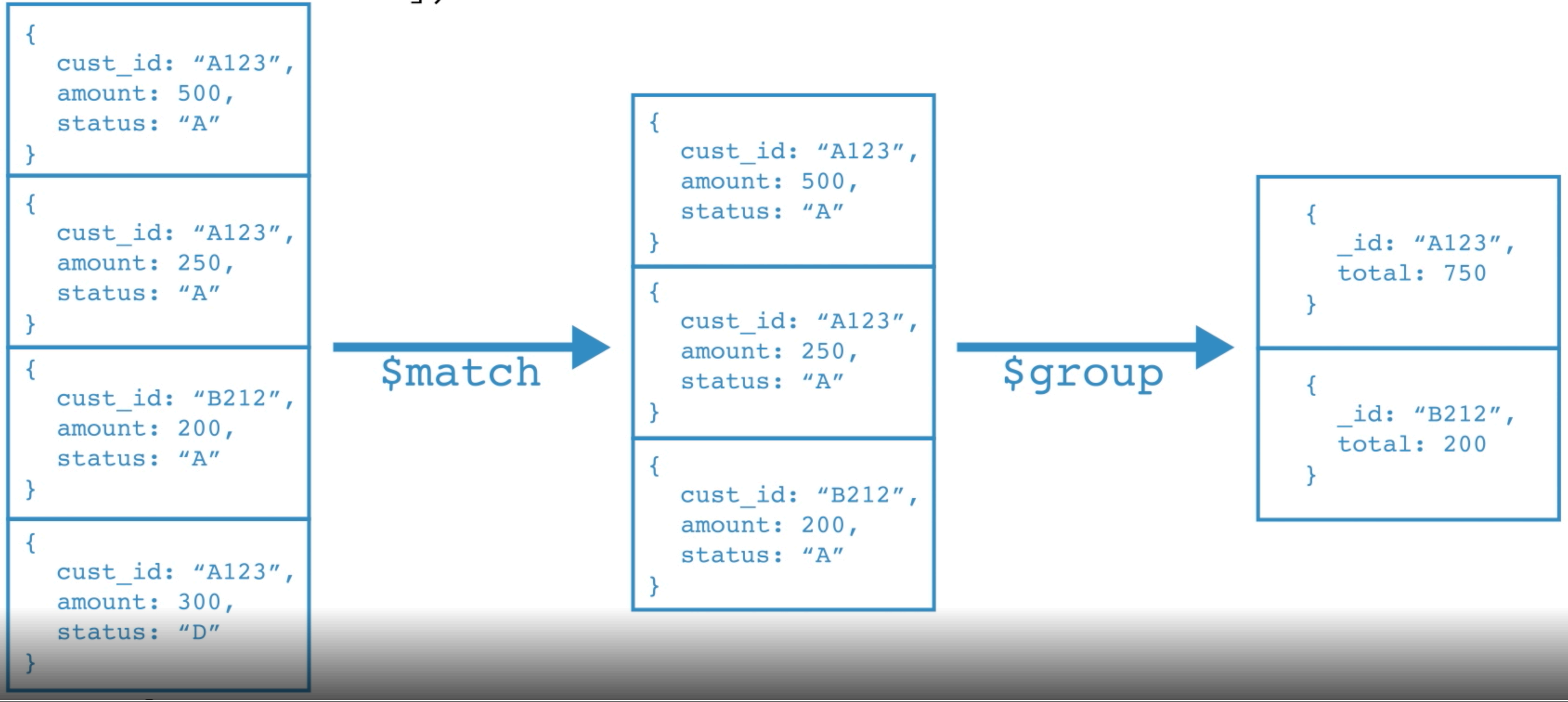
```
db.collection.aggregate ( [
 { $stage1Op: { } },
 { $stage2Op: { } },
  …
 { $stageNOp: { } }
] )
```

Collection

$match stage

$group stage

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



Orders

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

Grouping Example

```
db.sales.insertMany([
  { "_id" : 1, "item" : "abc", "price" : NumberDecimal("10"), "quantity" : NumberInt("2"), "date" : ISODate("2014-03-01T08:00:00Z") },
  { "_id" : 2, "item" : "jkl", "price" : NumberDecimal("20"), "quantity" : NumberInt("1"), "date" : ISODate("2014-03-01T09:00:00Z") },
  { "_id" : 3, "item" : "xyz", "price" : NumberDecimal("5"), "quantity" : NumberInt( "10"), "date" : ISODate("2014-03-15T09:00:00Z") },
  { "_id" : 4, "item" : "xyz", "price" : NumberDecimal("5"), "quantity" : NumberInt("20") , "date" : ISODate("2014-04-04T11:21:39.736Z") },
  { "_id" : 5, "item" : "abc", "price" : NumberDecimal("10"), "quantity" : NumberInt("10") , "date" : ISODate("2014-04-04T21:23:13.331Z") },
  { "_id" : 6, "item" : "def", "price" : NumberDecimal("7.5"), "quantity": NumberInt("5" ) , "date" : ISODate("2015-06-04T05:08:13Z") },
  { "_id" : 7, "item" : "def", "price" : NumberDecimal("7.5"), "quantity": NumberInt("10") , "date" : ISODate("2015-09-10T08:43:00Z") },
  { "_id" : 8, "item" : "abc", "price" : NumberDecimal("10"), "quantity" : NumberInt("5" ) , "date" : ISODate("2016-02-06T20:20:13Z") },
])
```

```
db.sales.aggregate( [
  {
    $group: {
       _id: null,
       count: { $sum: 1 }
    }
  }
] )
```

The operation returns the following result:

```
{ "_id" : null, "count" : 8 }
```

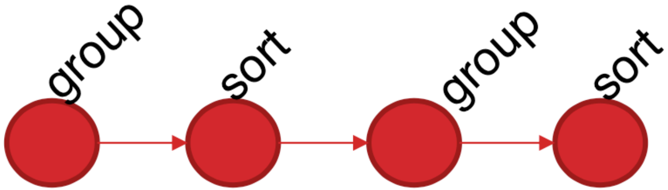
This aggregation operation is equivalent to the following SQL statement:

```
SELECT COUNT(*) AS count FROM sales
```

Multiple Agg. Example

Find, for every state, the biggest city and its population

```
aggregate( [
{ $group: { _id: { state: "$state", city: "$city" }, pop: { $sum: "$pop" } } },
{ $sort: { pop: -1 } },
{ $group: { _id : "$_id.state", bigCity: { $first: "$_id.city" }, bigPop: { $first: "$pop" } } },
{ $sort : {bigPop : -1} }
] )
```



Can list multiple aggregations after grouping id

Approach:
- Group by pair of city and state, and compute population per city
- Order by population descending
- Group by state, and find first city and population per group (i.e., the highest population city)
- Order by population descending

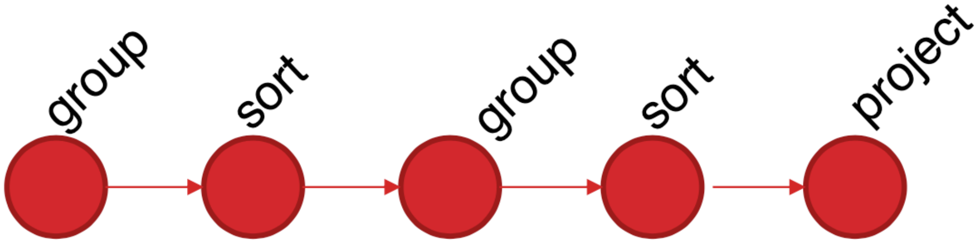
```
{ ”_id" : "IL", "bigCity" : "CHICAGO", "bigPop" : 2452177 }
{ "_id" : "NY", "bigCity" : "BROOKLYN", "bigPop" : 2300504 }
{ "_id" : "CA", "bigCity" : "LOS ANGELES", "bigPop" : 2102295 }
{ "_id" : "TX", "bigCity" : "HOUSTON", "bigPop" : 2095918 }
{ "_id" : "PA", "bigCity" : "PHILADELPHIA", "bigPop" : 1610956 }
{ "_id" : "MI", "bigCity" : "DETROIT", "bigPop" : 963243 }
```

Multiple Agg. with Vanilla Projection Example

If we only want to keep the state and city …

```
aggregate( [
{ $group: { _id: { state: "$state", city: "$city" }, pop: { $sum: "$pop" } } },
{ $sort: { pop: -1 } },
{ $group: { _id : "$_id.state", bigCity: { $first: "$_id.city" }, bigPop: { $first: "$pop" } } },
{ $sort : {bigPop : -1} }
{ $project : {bigPop : 0} }
] )
```

```
{ "_id" : "IL", "bigCity" : "CHICAGO" }
{ "_id" : "NY", "bigCity" : "BROOKLYN" }
{ "_id" : "CA", "bigCity" : "LOS ANGELES" }
{ "_id" : "TX", "bigCity" : "HOUSTON" }
{ "_id" : "PA", "bigCity" : "PHILADELPHIA" }
...
```



Multiple Agg. with Adv. Projection Example

If we wanted to nest the name of the city and population into a nested doc

```
aggregate( [
{ $group: { _id: { state: "$state", city: "$city" }, pop: { $sum: "$pop" } } },
{ $sort: { pop: -1 } },
{ $group: { _id : "$_id.state", bigCity: { $first: "$_id.city" }, bigPop: { $first: "$pop" } } },
{ $sort : {bigPop : -1} },
{ $project : { _id : 0, state : "$_id", bigCityDeets: { name: "$bigCity", pop: "$bigPop" } } }
] )
```

```
{ "state" : "IL", "bigCityDeets" : { "name" : "CHICAGO", "pop" : 2452177 } }
{ "state" : "NY", "bigCityDeets" : { "name" : "BROOKLYN", "pop" : 2300504 } }
{ "state" : "CA", "bigCityDeets" : { "name" : "LOS ANGELES", "pop" : 2102295 } }
{ "state" : "TX", "bigCityDeets" : { "name" : "HOUSTON", "pop" : 2095918 } }
{ "state" : "PA", "bigCityDeets" : { "name" : "PHILADELPHIA", "pop" : 1610956 } }
...
```

Can construct new nested documents in output, unlike vanilla projection

Advanced Projection vs. Vanilla Projection

- In addition to excluding/including fields like in projection during retrieval (find), projection in the aggregation pipeline allows you to:
  - Rename fields
  - Redefine new fields using complex expressions on old fields
  - Reorganize fields into nestings or unnestings
  - Reorganize fields into arrays or break down arrays

Unwinding Arrays

- Deconstructs an array field from the input documents to output a document for *each* element
- Each output document is the input document with the valu

```
db.inventory.insertOne({ "_id" : 1, "item" : "ABC1", sizes: [ "S", "M", "L"] })
```

The following aggregation uses the `$unwind` stage to output a document for each element in the `sizes` array:

```
db.inventory.aggregate( [ { $unwind : "$sizes" } ] )
```

The operation returns the following results:

```
{ "_id" : 1, "item" : "ABC1", "sizes" : "S" }
{ "_id" : 1, "item" : "ABC1", "sizes" : "M" }
{ "_id" : 1, "item" : "ABC1", "sizes" : "L" }
```

Looking Up Other Collections

- Conceptually, for each document
  - find documents in other collection that join (equijoin)
    - local field must match foreign field
  - place each of them in an array
- Thus, a left outer equi-join, with the join results stored in an array
- Recall: One of the key tenants of MongoDB schema design is to design to avoid the need for joins

Some Rules of Thumb when Writing Queries

- $project is helpful if you want to construct or deconstruct nestings (in addition to removing fields or creating new ones)
- $group is helpful to construct arrays (using $push or $addToSet)
- $unwind is helpful for unwinding arrays
- $lookup is your only hope for joins. Be prepared for a mess. Lots of $project needed

Creating Documents

```
db.products.insert({
"name" : "RayBan Sunglass Pro",
"sku" : "1590234",
"description" : "RayBan Sunglasses for professional sports people",
"inventory" : 100
})
```

```
db.products.insertMany([
    {
"name" : "GUCCI Handbag",
"sku" : "3451290",
"description" : "Fashion Hand bags for all ages",
"inventory" : 75
},
{
"name" : "Round hat",
"sku" : "8976045",
"inventory" : 200
},
{
"name" : "Polo shirt",
"sku" : "6497023",
"description" : "Cool shirts for hot summer",
"inventory" : 25
},
{
"name" : "Swim shorts",
"sku" : "8245352",
"description" : "Designer swim shorts for atheletes",
"inventory" : 200
},
{
"name" : "Running shoes",
"sku" : "3243662",
"description" : "Shoes for work out and trekking",
"inventory" : 20
}
])
```

```
{
    "acknowledged" : true,
    "insertedIds" : [
            ObjectId("5f2ef849ec2a4c45809ae553"),
            ObjectId("5f2ef849ec2a4c45809ae554"),
            ObjectId("5f2ef849ec2a4c45809ae555"),
            ObjectId("5f2ef849ec2a4c45809ae556"),
            ObjectId("5f2ef849ec2a4c45809ae557")
    ]
}
```

Updating Documents

```
db.products.update(
{"sku":"1590234"},
{
$set: {
"reviews" : [{
"rating" :4,
"review":"perfect glasses"
},{
"rating" :4.5,
"review":"my priced posession"
},{
"rating" :5,
"review":"Just love it"
}]}
}
)
```

The output indicates the number of documents that were matched, upserted and modified.

```
WriteResult({ "nMatched" : 1, "nUpserted" : 0, "nModified" : 1 })
```

```
{
"_id" : ObjectId("5f2ef40cec2a4c45809ae552"),
"name" : "RayBan Sunglass Pro",
"sku" : "1590234",
"description" : "RayBan Sunglasses for professional sports people",
"inventory" : 100,
"reviews" : [
        {
                "rating" : 4,
                "review" : "perfect glasses"
        },
        {
                "rating" : 4.5,
                "review" : "my priced posession"
        },
        {
                "rating" : 5,
                "review" : "Just love it"
        }
]
}
```

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Deleting Documents

```
db.products.remove({"sku":"8976045"})
```

The output indicates the number of documents removed

```
WriteResult({ "nRemoved" : 1 })
```

MongoDB: Summary

- 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!

MongoDB Demo

Reading and Next Class

- NoSQL
- Next: Transactions Part 1: Intro. to ACID: Ch 17