CSE 344

JULY 11TH

SEMI-STRUCTURED DATA

ADMINISTRATIVE MINUTIAE

- **HW3 due today**
- **HW4 out tomorrow (Datalog)**
- **WQ4 & WQ5 due Friday**
  - relational algebra & Datalog

NOSQL REVIEW

So far we have studied the relational data model

- Data is stored in tables(=relations)
- Queries are expressions in SQL, relational algebra, or Datalog

Traditional RDBMSs cannot scale to support modern web apps

- limited to one (big) machine
- scale web servers only until the DB becomes the bottleneck

NOSQL REVIEW

Scale up by spreading the data or requests across machines

- BUT consistency becomes much harder
  - may need to give up on consistency checks involving multiple rows
  - e.g., no checking of foreign key constraints
  - can still check column non-null, greater than 0, etc.
- BUT joins become much harder if data is spread across machines
  - may need give up on these
  - (we will see how to do these in a couple weeks)

NOSQL REVIEW

Original NoSQL systems put scalability before everything else

- For OLTP workloads only: users read/write small amount of data
  - huge database but each request looks at only a small part
- Simplest version *efficiently* supports only get/put of (key, value) pairs
  - provide no ability to join
  - provide no ability to select on anything but key!
  - these are “distributed hash tables” not databases
- Other types support extensible columns or documents
  - can efficiently select on anything in one row, but still no joins
- Scale data by partitioning across many servers
  - primary key is hashed to choose server where row lives
  - row-level consistency takes no inter-machine communication

NOSQL REVIEW

Two standard techniques (for distributed systems in general)

- partitioning: each row lives on only one machine
    - good for OLTP
    - consistency checks can be done on one machine
- replication: each row lives on all (or some) machines
    - bad for OLTP: machines could have different versions of a row
    - good for OLAP, assuming each machine has all the data
    - have all the data needed for joins on the machine
    - does not scale to large data, just large users / requests
- modern systems use both
    - e.g., partition primary copy, replicate (stale) backups

NOSQL REVIEW

Newer NoSQL systems can support full feature set

- research systems (e.g., Asterix) do this now
- expect to see production systems in the future

NoSQL now sometimes used to simply mean non-relational data

- semi-structured data (documents)

WHERE WE ARE

Today: Semistructured data model

- Popular formats today: XML, JSon, protobuf
    - book discusses XML (out of favor now)
    - we will discuss JSon
    - (protobuf is just a binary / condensed form of this)
- semi-structured data is more flexible for users
- no free lunch: lack of structure also has costs
    - less work when writing
    - more work when querying

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.

(History: easiest data format within the browser)

We will emphasize JSon as semi-structured data

JSON SYNTAX

```
{  "book": [
     {"id":"01",
        "language": "Java”,
        "author": ”H. Javeson”,
         “year”: 2015
     },
     {"id":"07",
        "language": "C++",
        "edition": "second"
        "author": ”E. Sepp”,
        “price”: 22.25
     }
  ]
}
```

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 Calculus

Semistructured 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 TERMINOLOGY

Data is represented in name/value pairs.

- Rows replaced by objects

Curly braces hold objects

- Each object is a list of name/value pairs separated by , (comma)
- Each pair is a name is followed by ':'(colon) followed by the value

Square brackets hold arrays and values are separated by ,(comma).

JSON DATA STRUCTURES

Collections of name-value pairs:

- {"name1": value1, "name2": value2, …}
- The "name" is also called a "key" (or "field")

Ordered lists of values:

- [obj1, obj2, obj3, ...]

AVOID USING DUPLICATE KEYS

The standard allows them, but many implementations don’t

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

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

JSON DATATYPES

Number

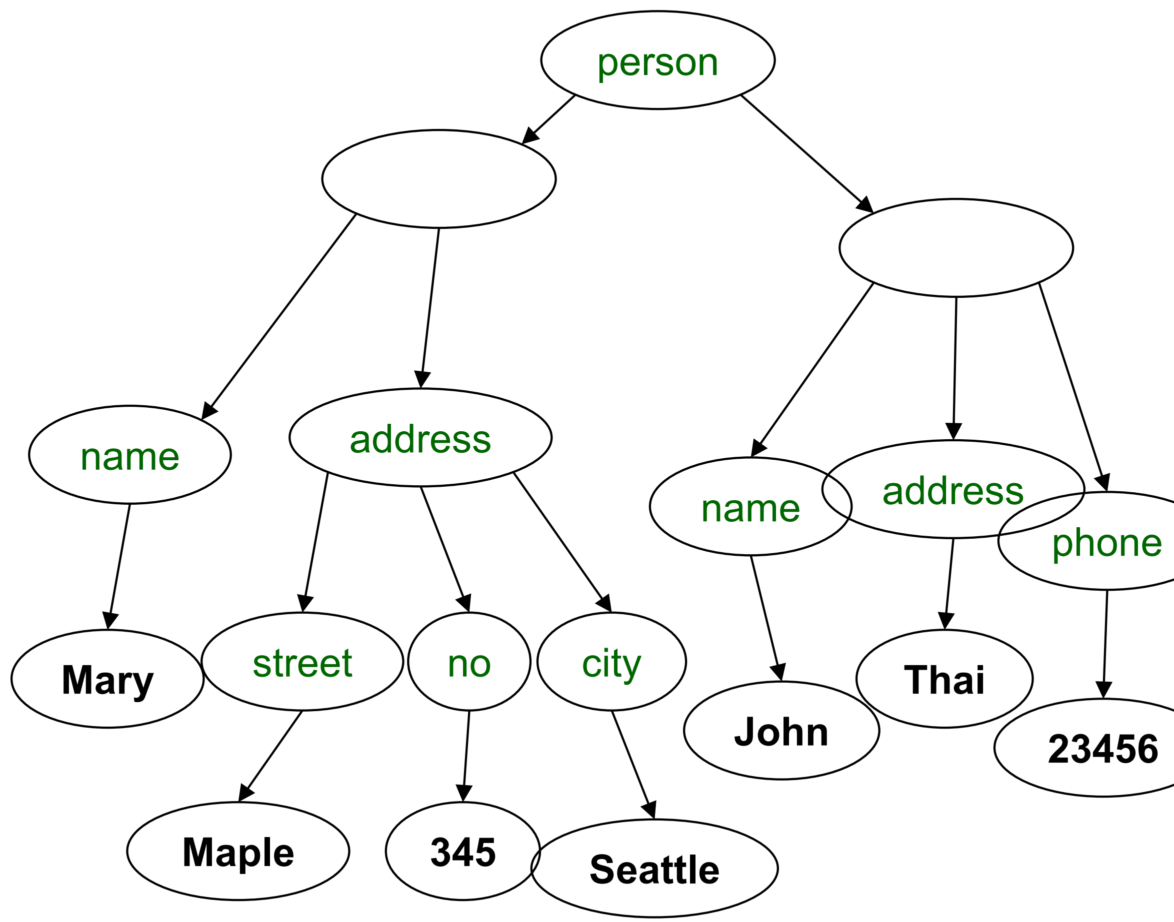
String = double-quoted

Boolean = true or false

null   empty

JSON SEMANTICS: A TREE !

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



JSON DATA

JSon is self-describing

Schema elements become part of the data

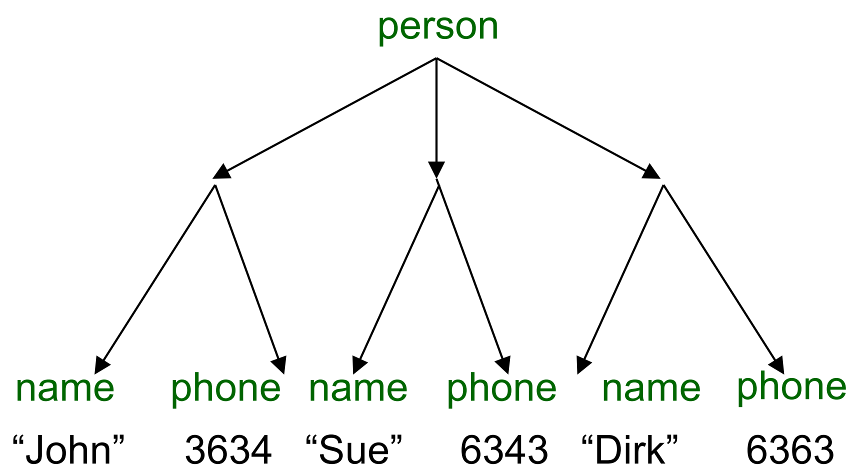
- Relational schema: person(name,phone)
- In Json "person", "name", "phone" are part of the data, and are repeated many times

Consequence: JSon is much more flexible (but wasteful)

JSon is also semistructured data

- (more soon...)

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 J

May inline 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”}
                      ]
        }
      ]
}
```

JSON=SEMI-STRUCTURED DATA (1/3)

Missing attributes:

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

no phone !

Could represent in a table with nulls

name	phone
John	1234
Joe	-

JSON=SEMI-STRUCTURED DATA (2/3)

Repeated attributes

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

Two phones !

Impossible in one table:

name	phone	
Mary	2345	3456

???

JSON=SEMI-STRUCTURED DATA (3/3)

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

- Downside: you need to think about these cases in queries!

QUERY LANGUAGES FOR SS DATA

XML: XPath, XQuery (textbook)

- Supported inside many RDBMS (SQL Server, DB2, Oracle)
- Several standalone XPath/XQuery engines
- XPath widely used in the browser: CSS, JQuery

JSon:

- CouchBase: N1QL, may be replaced by AQL (better designed)
- Asterix: SQL++ (based on SQL)
- MongoDB: has a pattern-based language
- JSONiq http://www.jsoniq.org/

ASTERIXDB AND SQL++

AsterixDB

- NoSQL database system
- Developed at UC Irvine
- Now an Apache project
- Own query language: AsterixQL or AQL, based on XQuery

SQL++

- SQL-like syntax for AsterixQL

ASTERIX DATA MODEL (ADM)

Objects:

- {“Name”: “Alice”, “age”: 40}
- Fields must be distinct:
  {“Name”: “Alice”, “age”: 40, ~~“age”:50~~}

Can’t have repeated fields

Arrays:

- [1, 3, “Fred”, 2, 9]
- Note: can be heterogeneous

Multisets:

- {{1, 3, “Fred”, 2, 9}}

EXAMPLES

Try these queries:

```
SELECT x.age FROM [{'name': 'Alice', 'age': ['30', '50']}] x;
```

```
SELECT x.age FROM {{ {'name': 'Alice', 'age': ['30', '50']} }} x;
```

Can only select from multi-set or array

```
-- error
SELECT x.age FROM {'name': 'Alice', 'age': ['30', '50']} x;
```

DATATYPES

Boolean, integer, float (various precisions), geometry (point, line, …), date, time, etc

UUID = universally unique identifier
Use it as a system-generated unique key

NULL V.S. MISSING

{“age”: null} = the value NULL (like in SQL)

{“age”: missing} = { } = really missing

```
SELECT x.b FROM [{'a':1, 'b':2}, {'a':3}] x;
```

```
{ "b": { "int64": 2 } }
{  }
```

```
SELECT x.b FROM [{'a':1, 'b':2}, {'a':3, 'b':missing }] x;
```

```
{ "b": { "int64": 2 } }
{  }
```

SQL++ OVERVIEW

Data Definition Language (DDL): create a

- Dataverse
- Type
- Dataset
- Index

Data Manipulation Language (DML): select-from-where

DATAVERSE

A Dataverse is a Database

```
CREATE DATAVERSE lec344
CREATE DATAVERSE lec344 IF NOT EXISTS

DROP DATAVERSE lec344
DROP DATAVERSE lec344 IF EXISTS

USE lec344
```

TYPE

Defines the schema of a collection

It lists all *<u>required</u>* fields

Fields followed by ? are *<u>optional</u>*

`CLOSED` type = no other fields allowed

`OPEN` type = other fields allowed

Semi-structured data

- type defines the structured part
- rest is unstructured

CLOSED TYPES

```
USE lec344;
DROP TYPE PersonType IF EXISTS;
CREATE TYPE PersonType AS CLOSED {
   Name : string,
   age: int,
   email: string?
}
```

{"Name": "Alice", "age": 30, "email": "a@alice.com"}

{"Name": "Bob", "age": 40}

-- not OK:
{"Name": "Carol", ~~"phone": "123456789"~~}

OPEN TYPES

```
USE lec344;
DROP TYPE PersonType IF EXISTS;
CREATE TYPE PersonType AS OPEN {
   Name : string,
   age: int,
   email: string?
}
```

```
{"Name": "Alice", "age": 30, "email": "a@alice.com"}

{"Name": "Bob", "age": 40}

-- Now it’s OK:
{"Name": "Carol", "phone": "123456789"}
```

TYPES WITH NESTED COLLECTIONS

```
USE lec344;
DROP TYPE PersonType IF EXISTS;
CREATE TYPE PersonType AS CLOSED {
   Name : string,
   phone: [string]
}
```

```
{"Name": "Carol", "phone": ["1234”]}
{"Name": ”David", "phone": [“2345”, “6789”]}
{"Name": ”Eric",  "phone": []}
```

DATASETS

Dataset = relation

Must have a type

- Can be a trivial `OPEN` type

Must have a key

- Can also be a trivial one

DATASET WITH EXISTING KEY

```
USE lec344;
DROP TYPE PersonType IF EXISTS;
CREATE TYPE PersonType AS CLOSED {
   Name : string,
   email: string?
}
```

```
{"Name": "Alice"}
{"Name": "Bob"}
…
```

```
USE lec344;
DROP DATASET Person IF EXISTS;
CREATE DATASET Person(PersonType) PRIMARY KEY Name;
```

DATASET WITH AUTO GENERATED KEY

```
USE lec344;
DROP TYPE PersonType IF EXISTS;
CREATE TYPE PersonType AS CLOSED {
   myKey: uuid,
   Name : string,
   email: string?
}
```

```
USE lec344;
DROP DATASET Person IF EXISTS;
CREATE DATASET Person(PersonType)
    PRIMARY KEY myKey AUTOGENERATED;
```

{"Name": "Alice"}
{"Name": "Bob"}
…

Note: no myKey since it will be autogenerated

DISCUSSION OF NFNF

NFNF = Non First Normal Form

One or more attributes contain a collection

One extreme: a single row with a huge, nested collection

Better: multiple rows, reduced number of nested collections

EXAMPLE

mondial.adm is totally semistructured:
{“mondial”: {“country”: [...], “continent”:[...], ..., “desert”:[...]}}

country	continent	organization	sea	...	mountain	desert
[{“name”:”Albania”,...}, {“name”:”Greece”,...}, ...]	...	...	...		...	...

country.adm, sea.adm, mountain.adm are more structured

Country:

-car_code	name	...	ethnicgroups	religions	...	city
AL	Albania	...	[...]	[...]	...	[...]
GR	Greece	...	[...]	[...]	...	[...]
...	...	...	...			

INDEXES

Can declare an index on an attribute of a top-most collection

- used to improve query performance
    - allows DBMS to perform certain lookups efficiently
- (more next week...)

Available:

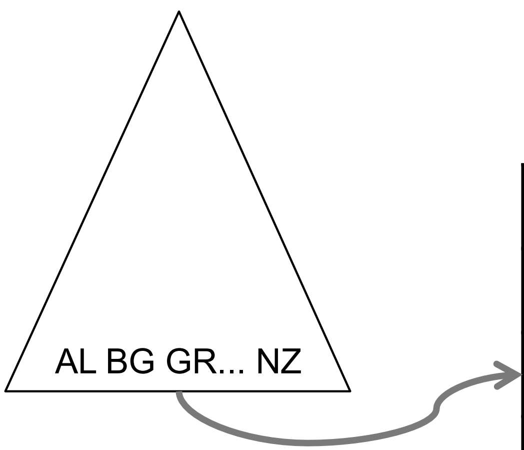
- BTREE: good for equality and range queries
  E.g. name="Greece"; 20 < age and age < 40
- RTREE: good for 2-dimensional range queries
  E.g. 20 < x and x < 40 and 10 < y and y < 50
- KEYWORD: good for substring search

INDEXES

Cannot index inside
a nested collection

```
USE lec344;
CREATE INDEX countryID
    ON country(`-car_code`)
    TYPE BTREE;
```

```
USE lec344;
CREATE INDEX cityname
    ON country(city.name)
    TYPE BTREE;
```



Country:

-car_code	name	...	ethnicgroups	religions	...	city
AL	Albania	...	[...]	[...]	...	[...]
GR	Greece	...	[...]	[...]	...	[...]
...	...	...	...			
BG	Belgium	...				
...						