CSE 344

FEBRUARY 2ND – SEMI-STRUCTURED DATA

ADMINISTRATIVE MINUTIAE

- **HW3 due Tonight, 11:30 pm**
- **OQ4 Due Wednesday, 11:00 pm**
- **HW4 due Friday 11:30 pm**
- **Exam next Friday**
  - 3:30 - 5:00

WHERE WE ARE

So far we have studied the *relational data model*

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

Today: Semistructured data model

- Popular formats today: XML, JSon, protobuf

DATA MODELS

Taxonomy based on data models:

Key-value stores

- e.g., Project Voldemort, Memcached

Document stores

- e.g., SimpleDB, CouchDB, MongoDB

Extensible Record Stores

- e.g., HBase, Cassandra, PNUTS

MOTIVATION

In Key, Value stores, the Value is often a very complex object

- Key = '2010/7/1', Value = [all flights that date]

Better: allow DBMS to understand the *value*

- Represent *value* as a JSON (or XML...) document
- [all flights on that date] = a JSON file
- May search for all flights on a given date

DOCUMENT STORES FEATURES

Data model: (key,document) pairs

- Key = string/integer, unique for the entire data
- Document = JSon, or XML

Operations

- Get/put document by key
- Query language over JSon

Distribution / Partitioning

- Entire documents, as for key/value pairs

We will discuss JSon

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.

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.

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”

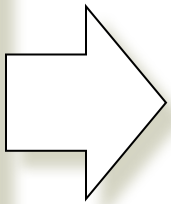
Ordered lists of values:

- [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

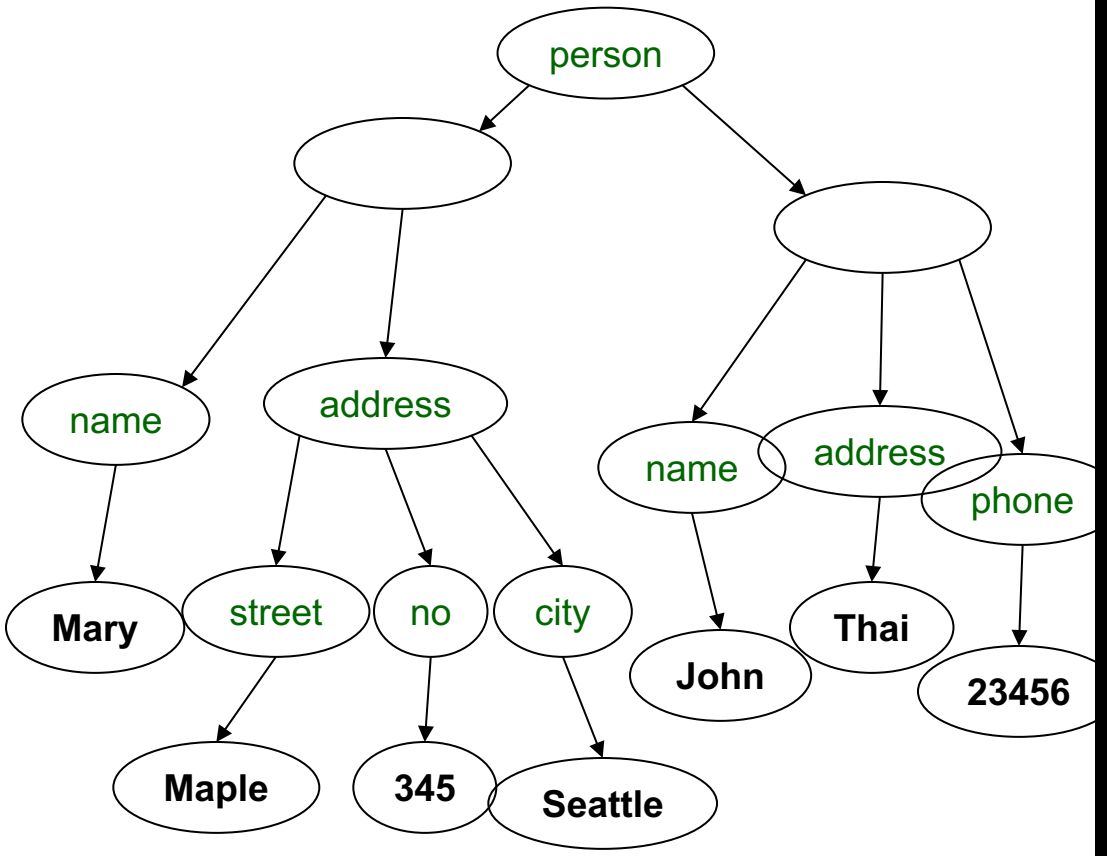
String = double-quoted

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

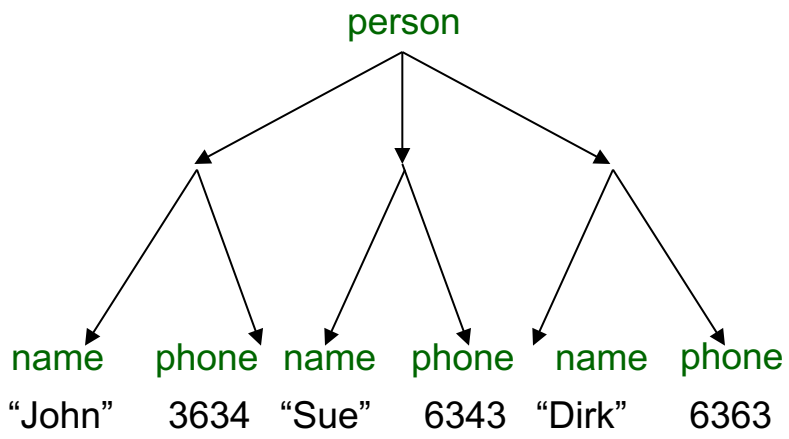
Schema elements become part of the data

- 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

JSon = semistructured data

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:

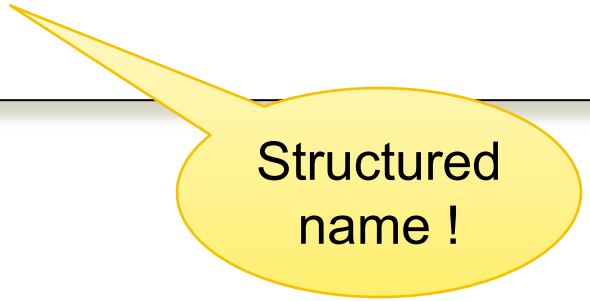
name	phone	
Mary	2345	3456

???

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}
    ]
}
```



Nested collections

Heterogeneous collections

QUERY LANGUAGES FOR SS DATA

XML: XPath, XQuery (see end of lecture, textbook)

- Supported inside many RDBMS (SQL Server, DB2, Oracle)
- Several standalone XPath/XQuery engines

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

- No-SQL 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 ***required*** fields

Fields followed by ? are ***optional***

`CLOSED` type = no other fields allowed

`OPEN` type = other fields allowed

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?
}
```

{“Name”: “Alice”}
{“Name”: “Bob”}
…

Note: no myKey since it will be autogenerated

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

Available:

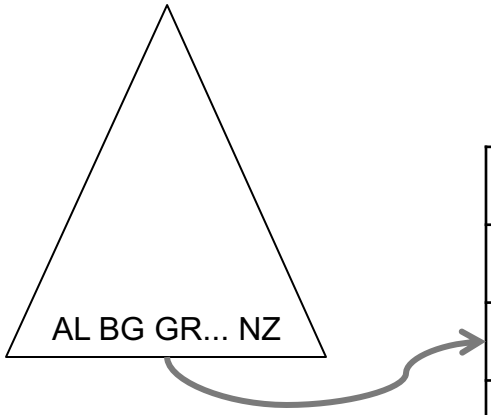
- BTREE: good for equality and range queries
  E.g. name="Greece"; 20 < age and age < 40
- RTREE: good for 2-dimensional range queries
  E.g. 20 < x and x < 40 and 10 < y and y < 50
- KEYWORD: good for substring search

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	...				
...						

SQL++ OVERVIEW

```
SELECT ... FROM ... WHERE ... [GROUP BY ...]
```

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

RETRIEVE EVERYTHING

```
SELECT x.mondial FROM world x;
```

Answer

```
{“mondial”:
      {“country”: [ country1, country2, …],
      “continent”: […],
      “organization”: […],
      …
      …
}
```

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

RETRIEVE COUNTRIES

```
SELECT x.mondial.country FROM world x;
```

Answer

```
{“country”: [ country1, country2, …],
```

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

RETRIEVE COUNTRIES, ONE BY ONE

```
SELECT y as country FROM world x, x.mondial.country y;
```

Answer

country1
country2
…

ESCAPE CHARACTERS

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

“-car_code” illegal field
Use ` ... `

```
SELECT y.`-car_code` as code , y.name as name
FROM world x, x.mondial.country y order by y.name;
```

Answer

```
{“code”: “AFG”, “name”: “Afganistan”}
{“code”: “AL”, “name”: “Albania”}
…
```

NESTED COLLECTIONS

If the value of attribute B is a collection, then we simply iterate over it

```
SELECT x.A, y.C, y.D
FROM mydata as x, x.B as y;
```

x.B is a collection

```
{"A": "a1", "B": [{"C": "c1", "D": "d1"}, {"C": "c2", "D": "d2"}]}
{"A": "a2", "B": [{"C": "c3", "D": "d3"}]}
{"A": "a3", "B": [{"C": "c4", "D": "d4"}, {"C": "c5", "D": "d5"}]}
```

NESTED COLLECTIONS

If the value of attribute B is a collection, then we simply iterate over it

```
SELECT x.A, y.C, y.D
FROM mydata as x, x.B as y;
```

x.B is a collection

```
{"A": "a1", "B": [{"C": "c1", "D": "d1"}, {"C": "c2", "D": "d2"}]}
{"A": "a2", "B": [{"C": "c3", "D": "d3"}]}
{"A": "a3", "B": [{"C": "c4", "D": "d4"}, {"C": "c5", "D": "d5"}]}
```

```
{"A": "a1", "C": "c1", "D": "d1"}
{"A": "a1", "C": "c2", "D": "d2"}
{"A": "a2", "C": "c3", "D": "d3"}
{"A": "a3", "C": "c4", "D": "d4"}
{"A": "a3", "C": "c5", "D": "d5"}
```

HETEROGENEOUS COLLECTIONS

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

Runtime error

```
SELECT z.name as province_name, u.name as city_name
FROM world x, x.mondial.country y, y.province z, z.city u
WHERE  y.name='Greece';
```

The problem:

```
…
“province”: [ ...
    {“name”: "Attiki”,
     “city” : [ {“name”: ”Athens”...}, {“name”: ”Pireus”...}, ..]
      ...},
     {“name”: ”Ipiros”,
     “city” : {“name”: ”Ioannia”...}
      ...},
```

city is an array

city is an object

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      …
      …
}
```

HETEROGENEOUS COLLECTIONS

```
SELECT z.name as province_name, u.name as city_name
FROM world x, x.mondial.country y, y.province z, z.city u
WHERE  y.name='Greece' and is_array(z.city);
```

The problem:

```
…
“province”: [ ...
    {“name”: "Attiki”,
     “city” : [ {“name”: ”Athens”...}, {“name”: ”Pireus”...}, ..]
      ...},
     {“name”: ”Ipiros”,
     “city” : {“name”: ”Ioannia”...}
      ...},
```

Just the arrays

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      ...
      ...
}
```

HETEROGENEOUS COLLECTIONS

Note: get name directly from z

```
SELECT z.name as province_name, z.city.name as city_name
FROM world x, x.mondial.country y, y.province z
WHERE  y.name='Greece' and not is_array(z.city);
```

Just the objects

The problem:

```
…
“province”: [ ...
    {“name”: "Attiki”,
     “city” : [ {“name”: ”Athens”...}, {“name”: ”Pireus”...}, ..]
      ...},
     {“name”: ”Ipiros”,
     “city” : {“name”: ”Ioannia”...}
      ...},
```

HETEROGENEOUS COLLECTIONS

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      ...
      ...
}
```

```
SELECT z.name as province_name, u.name as city_name
FROM world x, x.mondial.country y, y.province z,
          (CASE  WHEN is_array(z.city) THEN z.city
           ELSE  [z.city] END) u
WHERE  y.name='Greece';
```

Get both!

The problem:

```
…
“province”: [ ...
    {“name”: "Attiki”,
     “city” : [ {“name”: ”Athens”...}, {“name”: ”Pireus”...}, ..]
      ...},
     {“name”: ”Ipiros”,
     “city” : {“name”: ”Ioannia”...}
      ...},
```

HETEROGENEOUS COLLECTIONS

```
{“mondial”:
    {“country”: [ country1, country2, …],
     “continent”: […],
      “organization”: […],
      ...
      ...
}
```

```
SELECT z.name as province_name, u.name as city_name
FROM world x, x.mondial.country y, y.province z,
        (CASE  WHEN z.city is missing THEN []
                    WHEN is_array(z.city) THEN z.city
                    ELSE  [z.city] END)  u
WHERE  y.name='Greece';
```

Th[illegible]

```
…
“province”: [ ...
    {“name”: "Attiki”,
     “city” : [ {“name”: ”Athens”...}, {“name”: ”Pireus”...}, ..]
      ...},
     {“name”: ”Ipiros”,
     “city” : {“name”: ”Ioannia”...}
      ...},
```

Even better

USEFUL FUNCTIONS

is_array

is_boolean

is_number

is_object

is_string

is_null

is_missing

is_unknown = is_null or is_missing

NEXT WEEK

- **Finish discussion of SQL++**
- **Wednesday – Exam Review**
- **Section – Exam Review**
- **Friday – Exam**
  - 3:30 – 4:50
  - No Office Hours
- **Exams back next week in section**