# CSE 344

## JULY 13TH

## SQL++

# ADMINISTRATIVE MINUTIAE

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

# REVIEW

**Semistructured data**

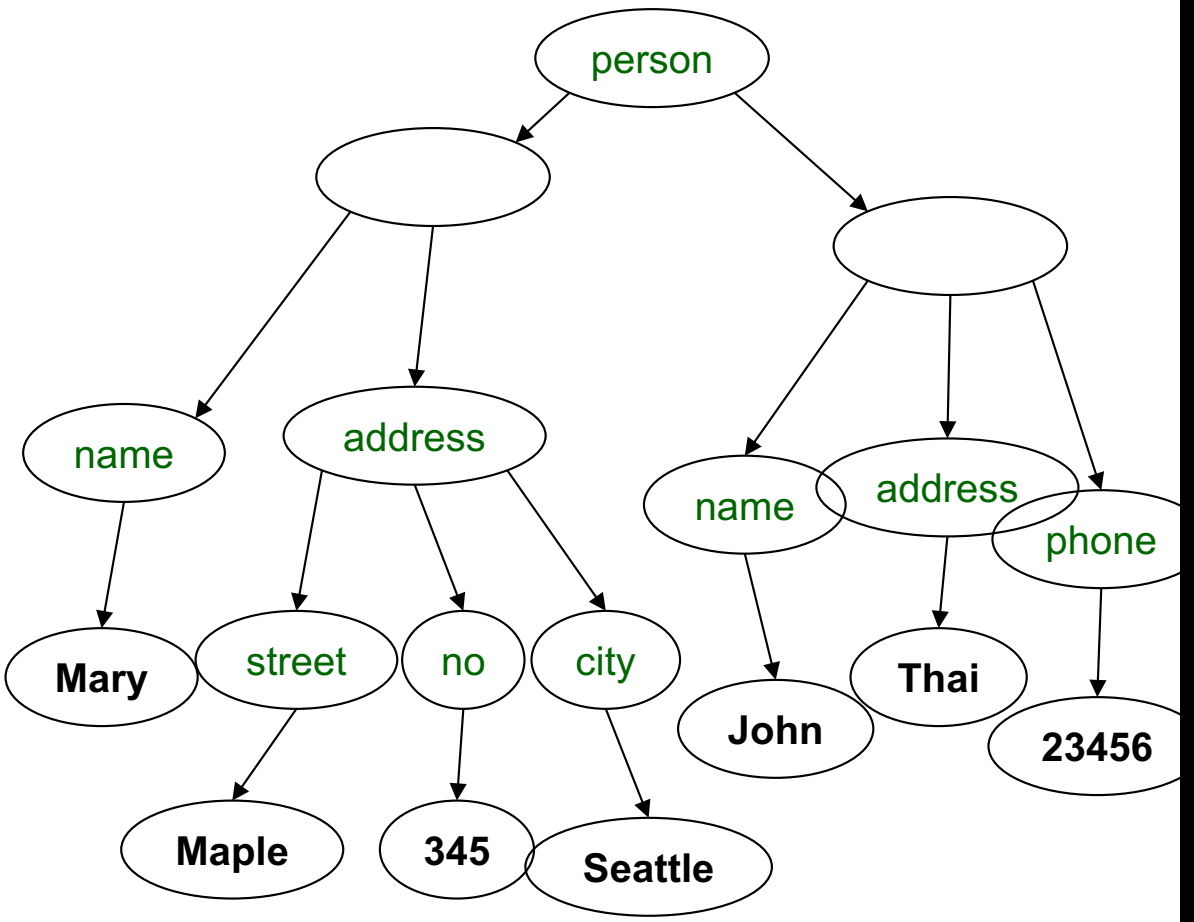
- Row tuples replaced with row objects ("documents")
  - row is a tuple, e.g., (1, 2, 'foo') $\in$ Int x Int x String
  - objects have fields where values can be objects, lists, etc.
    - NFNF
- Set of tuples (table) replaced with lists or multisets of objects

**NoSQL**

- Early systems found it easy to support more flexible formats
  - due to the limited feature set (no joins, less consistency)
- Newer systems support the complete RDBMS feature set
  - e.g., AsterixDB

# JSON SEMANTICS: A TREE !

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



# 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)

**Primitive Types: Number, String, Boolean, etc.**

**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}}

# 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", ”age”: 35, ~~"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", ”age”: 35, "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;
```

# 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);
```

Just the arrays

The problem:

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

```
{“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

```
...
“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

# USEFUL PARADIGMS

**Unnesting**

**Nesting**

**Group-by / aggregate**

**Join**

**Multi-value join**

# BASIC UNNESTING

**An array: [a, b, c]**

**A nested array: arr = [[a, b], [], [b, c, d]]**

**`Unnest(arr)` = [a, b, b, c, d]**

```
SELECT y
FROM arr x, x y
```

# UNNESTING SPECIFIC FIELD

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

# UNNESTING SPECIFIC FIELD

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Nested Relational Algebra

$Unnest_F(coll)$ =

```
[{A:a1, B:b1, G:[{C:c1}]},
 {A:a1, B:b2, G:[{C:c1}]},
 {A:a2, B:b3, G:[]},
 {A:a2, B:b4, G:[]},
 {A:a2, B:b5, G:[]},
 {A:a3, B:b6, G:[{C:c2},{C:c3}]}]
```

# UNNESTING SPECIFIC FIELD

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Nested Relational Algebra

$Unnest_F(coll)$ =

```
[{A:a1, B:b1, G:[{C:c1}]},
 {A:a1, B:b2, G:[{C:c1}]},
 {A:a2, B:b3, G:[]},
 {A:a2, B:b4, G:[]},
 {A:a2, B:b5, G:[]},
 {A:a3, B:b6, G:[{C:c2},{C:c3}]}]
```

SQL++

```
SELECT x.A, y.B, x.G
FROM coll x, x.F y
```

Refers to relations defined on the left

# UNNESTING SPECIFIC FIELD

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Nested Relational Algebra

$Unnest_F(coll)$ =

```
[{A:a1, B:b1, G:[{C:c1}]},
 {A:a1, B:b2, G:[{C:c1}]},
 {A:a2, B:b3, G:[]},
 {A:a2, B:b4, G:[]},
 {A:a2, B:b5, G:[]},
 {A:a3, B:b6, G:[{C:c2},{C:c3}]}]
```

```
SELECT x.A, y.B, x.G
FROM coll x, x.F y
```

=

SQL++

```
SELECT x.A, y.B, x.G
FROM coll x
UNNEST x.F y
```

# UNNESTING SPECIFIC FIELD

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Nested Relational Algebra

$Unnest_G$(coll) =

```
[{A:a1, F:[{B:b1},{B:b2}], C:c1},
 {A:a3, F:[{B:b6}], C:c2},
 {A:a3, F:[{B:b6}], C:c3]}
```

$Unnest_F$(coll) =

```
[{A:a1, B:b1, G:[{C:c1}]},
 {A:a1, B:b2, G:[{C:c1}]},
 {A:a2, B:b3, G:[]},
 {A:a2, B:b4, G:[]},
 {A:a2, B:b5, G:[]},
 {A:a3, B:b6, G:[{C:c2},{C:c3}]}]
```

SQL++

```
SELECT x.A, y.B, x.G
FROM coll x, x.F y
```

```
SELECT x.A, x.F, z.C
FROM coll x, x.G z
```

# NESTING (LIKE GROUP-BY)

A flat collection

```
coll =
[{A:a1, B:b1}, {A:a1, B:b2}, {A:a2, B:b1}]
```

# NESTING (LIKE GROUP-BY)

A flat collection

coll =
[{A:a1, B:b1}, {A:a1, B:b2}, {A:a2, B:b1}]

Nested Relational Algebra

$Nest_A$(coll) =
[{A:a1, GRP:[{B:b1},{B:b2}]}
 [{A:a2, GRP:[{B:b2}]}]

$Nest_B$(coll) =
[{B:b1, GRP:[{A:a1},{A:a2}]},
 {B:b2, GRP:[{A:a1}]}]

# NESTING (LIKE GROUP-BY)

A flat collection

```
coll =
[{A:a1, B:b1}, {A:a1, B:b2}, {A:a2, B:b1}]
```

Nested Relational Algebra

$Nest_A$(coll) =
[{A:a1, GRP:[{B:b1},{B:b2}]}
 [{A:a2, GRP:[{B:b2}]}]

$Nest_B$(coll) =
[{B:b1, GRP:[{A:a1},{A:a2}]},
 {B:b2, GRP:[{A:a1}]}]

```
SELECT DISTINCT x.A,
    (SELECT y.B FROM coll y WHERE x.A = y.A) as GRP
FROM coll x
```

# NESTING (LIKE GROUP-BY)

A flat collection

```
coll =
[{A:a1, B:b1}, {A:a1, B:b2}, {A:a2, B:b1}]
```

Nested Relational Algebra

$Nest_A$(coll) =
[{A:a1, GRP:[{B:b1},{B:b2}]}
 [{A:a2, GRP:[{B:b2}]}]

$Nest_B$(coll) =
[{B:b1, GRP:[{A:a1},{A:a2}]},
 {B:b2, GRP:[{A:a1}]}]

```
SELECT DISTINCT x.A,
    (SELECT y.B FROM coll y WHERE x.A = y.A) as GRP
FROM coll x
```

```
SELECT DISTINCT x.A, g as GRP
FROM coll x
LET g =  (SELECT y.B FROM coll y WHERE x.A = y.A)
```

# GROUP-BY / AGGREGATE

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Count the number of elements in the F collection

# GROUP-BY / AGGREGATE

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a3, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Count the number of elements in the F collection

```
SELECT x.A, COLL_COUNT(x.F) as cnt
FROM coll x
```

# GROUP-BY / AGGREGATE

| Function | NULL | MISSING | Empty Collection |
|---|---|---|---|
| COLL_COUNT | counted | counted | 0 |
| COLL_SUM | returns NULL | returns NULL | returns NULL |
| COLL_MAX | returns NULL | returns NULL | returns NULL |
| COLL_MIN | returns NULL | returns NULL | returns NULL |
| COLL_AVG | returns NULL | returns NULL | returns NULL |
| ARRAY_COUNT | not counted | not counted | 0 |
| ARRAY_SUM | ignores NULL | ignores NULL | returns NULL |
| ARRAY_MAX | ignores NULL | ignores NULL | returns NULL |
| ARRAY_MIN | ignores NULL | ignores NULL | returns NULL |
| ARRAY_AVG | ignores NULL | ignores NULL | returns NULL |

# JOIN

Two flat collection

```
coll1 = [{A:a1, B:b1}, {A:a1, B:b2}, {A:a2, B:b1}]
coll2 = [{B:b1,C:c1}, {B:b1,C:c2}, {B:b3,C:c3}]
```

```
SELECT x.A, x.B, y.C
FROM coll1 x, coll2 y
WHERE x.B = y.B
```

# MULTI-VALUE JOIN

**Recall: a many-to-one relation should have one foreign key, from “many” to “one”**

**Sometimes people represent it in the opposite direction, from “one” to “many”:**

- The reference is a string of keys separated by space
- Need to use split(string, separator) to split it into a collection of foreign keys

# MULTI-VALUE JOIN

```
 river =
[{"name": "Donau”, "-country": "SRB A D H HR SK BG RO MD UA”},
 {"name": "Colorado”, "-country": "MEX USA”},
  ... ]
```

# MULTI-VALUE JOIN

```
river =
[{"name": "Donau", "-country": "SRB A D H HR SK BG RO MD UA"},
 {"name": "Colorado", "-country": "MEX USA"},
  ... ]
```


split("MEX USA", " ") =
["MEX", "USA"]

# MULTI-VALUE JOIN

```
river =
[{"name": "Donau", "-country": "SRB A D H HR SK BG RO MD UA"},
 {"name": "Colorado", "-country": "MEX USA"},
  ... ]
```

```
SELECT ...
FROM country x, river y,
        split(y. `-country`, " ") z
WHERE x.`-car_code` = z
```

String

Separator

split("MEX USA", " ") =
["MEX", "USA"]

# BEHIND THE SCENES

**Query Processing on NFNF data:**

**Option 1: give up on query plans, use standard java/python-like execution**

**Option 2: represent the data as a collection of flat tables, convert SQL++ to a standard relational query plan**

# FLATTENING SQL++ QUERIES

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a1, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

# FLATTENING SQL++ QUERIES

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a1, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

Flat Representation

coll:

| id | A |
|---|---|
| 1 | a1 |
| 2 | a2 |
| 3 | a1 |

F

| parent | B |
|---|---|
| 1 | b1 |
| 1 | b2 |
| 2 | b3 |
| 2 | b4 |
| 2 | b5 |
| 3 | b6 |

G

| parent | C |
|---|---|
| 1 | c1 |
| 3 | c2 |
| 3 | c3 |

# FLATTENING SQL++ QUERIES

A nested collection

```
coll =
[{A:a1, F:[{B:b1},{B:b2}], G:[{C:c1}]},
 {A:a2, F:[{B:b3},{B:b4},{B:b5}], G:[ ]},
 {A:a1, F:[{B:b6}], G:[{C:c2},{C:c3}]}]
```

SQL++

```
SELECT x.A, y.B
FROM coll x, x.F y
WHERE x.A = 'a1'
```

Flat Representation

coll:

| id | A |
|---|---|
| 1 | a1 |
| 2 | a2 |
| 3 | a1 |

F

| parent | B |
|---|---|
| 1 | b1 |
| 1 | b2 |
| 2 | b3 |
| 2 | b4 |
| 2 | b5 |
| 3 | b6 |

G

| parent | C |
|---|---|
| 1 | c1 |
| 3 | c2 |
| 3 | c3 |

SQL

```
SELECT x.A, y.B
FROM coll x, F y
WHERE x.id = y.parent and x.A = 'a1'
```

# SEMISTRUCTURED DATA MODEL

**Several file formats: Json, protobuf, XML**

**The data model is a tree**

**They differ in how they handle structure:**

- Open or closed
- Ordered or unordered

# CONCLUSION

**Semistructured data best suited for *data exchange***

**For quick, ad-hoc data analysis, use a native query language: SQL++, or AQL, or XQuery**

- Modern, advanced query processors like AsterixDB / SQL++ can process semistructured data as efficiently as RDBMS

**For long term data analysis: spend the time and effort to normalize it, then store in a RDBMS**