SQL Recursion

```
WITH
    stuff that looks like Datalog rules
an SQL query about EDB, IDB
```

- Rule =

  `[RECURSIVE]` R(<arguments>) `AS`

  SQL query

Example

Find Sally's cousins, using EDB `Par(child, parent)`.

```
WITH
    Sib(x,y) AS
        SELECT p1.child, p2,child
        FROM Par p1, Par p2
        WHERE p1.parent = p2.parent
            AND p1.child <> p2.child,

    RECURSIVE Cousin(x,y) AS
        Sib
            UNION
        (SELECT p1.child, p2.child
         FROM Par p1, Par p2, Cousin
         WHERE p1.parent = Cousin.x
             AND p2.parent = Cousin.y
        )

SELECT y
FROM Cousin
WHERE x = 'Sally';
```

Plan for Describing Legal SQL recursion

1. Define "monotonicity," a property that generalizes "stratification."

2. Generalize stratum graph to apply to SQL queries instead of Datalog rules.

   ✦ (Non)monotonicity replaces `NOT` in subgoals.

3. Define semantically correct SQL recursions in terms of stratum graph.

Monotonicity

If relation P is a function of relation Q (and perhaps other things), we say P is *monotone* in Q if adding tuples to Q cannot cause any tuple of P to be deleted.

Monotonicity Example

In addition to certain negations, an aggregation can cause nonmonotonicity.

```
Sells(bar, beer, price)

SELECT AVG(price)
FROM Sells
WHERE bar = 'Joe''s Bar';
```

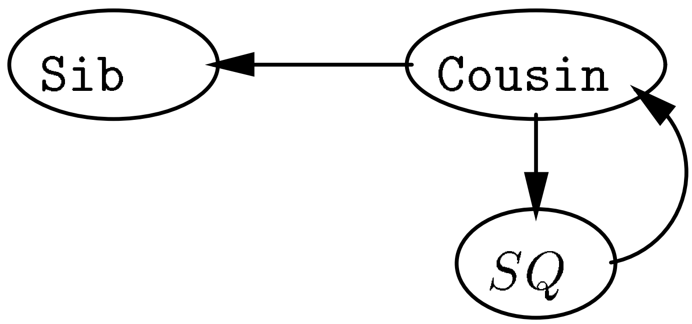
- Adding to `Sells` a tuple that gives a new beer Joe sells will usually change the average price of beer at Joe's.
- Thus, the former result, which might be a single tuple like (2.78) becomes another single tuple like (2.81), and the old tuple is lost.

Generalizing Stratum Graph to SQL

- Node for each relation defined by a "rule."
- Node for each subquery in the "body" of a rule.
- Arc $P \rightarrow Q$ if
  a) P is "head" of a rule, and Q is a relation appearing in the `FROM` list of the rule (not in the `FROM` list of a subquery), as argument of a `UNION`, etc.
  b) P is head of a rule, and Q is a subquery directly used in that rule (not nested within some larger subquery).
  c) P is a subquery, and Q is a relation or subquery used directly within P [analogous to (a) and (b) for rule heads].
- Label the arc $-$ if P is *not* monotone in Q.
- Requirement for legal SQL recursion: finite strata only.

Example

For the Sib/Cousin example, there are three nodes: `Sib`, `Cousin`, and SQ (the second term of the union in the rule for `Cousin`).



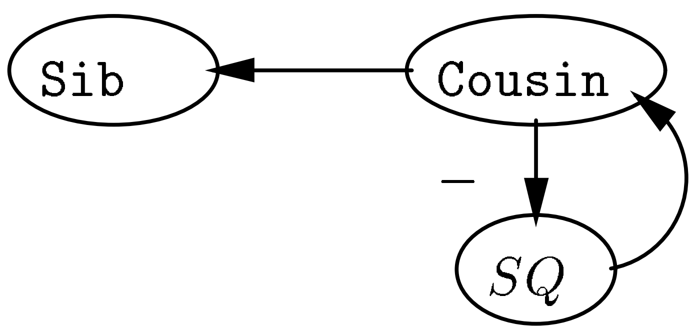
- No nonmonotonicity, hence legal.

A Nonmonotonic Example

Change the `UNION` to `EXCEPT` in the rule for `Cousin`.

```
RECURSIVE Cousin(x,y) AS
    Sib
        EXCEPT
    (SELECT p1.child, p2.child
     FROM Par p1, Par p2, Cousin
     WHERE p1.parent = Cousin.x
         AND p2.parent = Cousin.y
    )
```

- Now, adding to the result of the subquery can delete `Cousin` facts; i.e., `Cousin` is nonmonotone in SQ.



- Infinite number of $-$'s in cycle, so illegal in SQL.

Another Example: `NOT` Doesn't Mean Nonmonotone

Leave `Cousin` as it was, but negate one of the conditions in the where-clause.

```
RECURSIVE Cousin(x,y) AS
     Sib
          UNION
     (SELECT p1.child, p2.child
      FROM Par p1, Par p2, Cousin
      WHERE p1.parent = Cousin.x
           AND NOT (p2.parent = Cousin.y)
     )
```

- You might think that SQ depends negatively on `Cousin`, but it doesn't.
  - ✦ If I add a new tuple to `Cousin`, all the old tuples still exist and yield whatever tuples in SQ they used to yield.
  - ✦ In addition, the new `Cousin` tuple might combine with old $p1$ and $p2$ tuples to yield something new.

Object-Oriented DBMS's

- ODMG = Object Data Management Group: an OO standard for databases.
- ODL = Object Description Language: design in the OO style.
- OQL = Object Query Language: queries an OO database with an ODL schema, in a manner similar to SQL.

ODL Overview

Class declarations include:

1. Name for the class.
2. Key declaration(s), which are optional.
3. *Extent* declaration = name for the set of currently existing objects of a class.
4. *Element* declarations. An element is an attribute, a relationship, or a method.

ODL Class Declarations

```
class <name> {
    elements = attributes, relationships,
        methods
}
```

Element Declarations

```
attribute <type> <name>;
relationship <rangetype> <name>;
```

- Relationships involve objects; attributes (usually) involve non-object values, e.g., integers.

Method Example

```
float gpa(in string) raises(noGrades)
```

- `float` = return type.
- `in`: indicates the argument (a student name, presumably) is read-only.
  - ✦ Other options: `out`, `inout`.
- `noGrades` is an exception that can be raised by method `gpa`.

ODL Relationships

- Only binary relations supported.
  - ✦ Multiway relationships require a "connecting" class, as discussed for E/R model.
- Relationships come in inverse pairs.
  - ✦ Example: "Sells" between beers and bars is represented by a relationship in bars, giving the beers sold, *and* a relationship in beers giving the bars that sell it.
- Many-many relationships have a set type (called a *collection type*) in each direction.
- Many-one relationships have a set type for the one, and a simple class name for the many.
- One-one relations have classes for both.

Beers-Bars-Drinkers Example

```
class Beers {
    attribute string name;
    attribute string manf;
    relationship Set<Bars> servedAt
        inverse Bars::serves;
    relationship Set<Drinkers> fans
        inverse Drinkers::likes;
}
```

- An element from another class is indicated by <class>::
- Form a set type with `Set<type>`.

```
class Bars {
    attribute string name;
    attribute Struct Addr
        {string street, string city, int zip}
            address;
    attribute Enum Lic {full, beer, none}
            licenseType;
    relationship Set<Drinkers> customers
        inverse Drinkers::frequents;
    relationship Set<Beers> serves
        inverse Beers::servedAt;
}
```

- Structured types have names and bracketed lists of field-type pairs.
- Enumerated types have names and bracketed lists of values.

```
class Drinkers {
    attribute string name;
    attribute Struct Bars::Addr
            address;
    relationship Set<Beers> likes
        inverse Beers::fans;
    relationship Set<Bars> frequents
        inverse Bars::customers;
}
```

- Note reuse of `Addr` type.

ODL Type System

- Basic types: int, real/float, string, enumerated types, and classes.
- Type constructors: `Struct` for structures and five *collection types*: `Set`, `Bag`, `List`, `Array`, and `Dictionary`.
- Relationship types many only be classes or a collection of a class.

Many-One Relationships

Don't use a collection type for relationship in the "many" class.

Example: Drinkers Have Favorite Beers

```
class Drinkers {
    attribute string name;
    attribute Struct Bars::Addr
            address;
    relationship Set<Beers> likes
        inverse Beers::fans;
    relationship Beers favoriteBeer
        inverse Beers::realFans;
    relationship Set<Bars> frequents
        inverse Bars::customers;
}
```

- Also add to `Beers`:

```
    relationship Set<Drinkers> realFans
        inverse Drinkers::favoriteBeer;
```

Example: Multiway Relationship

Consider a 3-way relationship bars-beers-prices. We have to create a connecting class `BBP`.

```
class Prices {
    attribute real price;
    relationship Set<BBP> toBBP
        inverse BBP::thePrice;
}

class BBP {
    relationship Bars theBar inverse ...
    relationship Beers theBeer inverse ...
    relationship Prices thePrice
        inverse Prices::toBBP;
}
```

- Inverses for `theBar`, `theBeer` must be added to `Bars`, `Beers`.
- Better in this special case: make no `Prices` class; make `price` an attribute of `BBP`.
- Notice that keys are optional.
  - `BBP` has no key, yet is not "weak." Object identity suffices to distinguish different `BBP` objects.

Roles in ODL

Names of relationships handle "roles."

Example: Spouses and Drinking Buddies

```
class Drinkers {
    attribute string name;
    attribute Struct Bars::Addr
            address;
    relationship Set<Beers> likes
        inverse Beers::fans;
    relationship Set<Bars> frequents
        inverse Bars::customers;
    relationship Drinkers husband
        inverse wife;
    relationship Drinkers wife
        inverse husband;
    relationship Set<Drinkers> buddies
        inverse buddies;
}
```

- Notice that `Drinkers::` is optional when the inverse is a relationship of the same class.