Towards Bridging the Expressiveness Gap Between Relational and Deductive Databases

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Outline

1. Introduction
2. DES
3. Enabling Interoperability
4. Extending DBMS Expressiveness
5. Performance
6. Conclusions

1. Introduction – Expressiveness Gap

- Expressiveness:
  - Expressive Power (Theoretical Expressiveness)
    - What things can I say?
  - Conciseness and Readiness (Practical Expressiveness)
    - How much will it cost to me?

1. Introduction – Languages

- Relational languages:
  - Relational Algebra
  - (Tuple, Domain) Relational Calculus
  - SQL
- Deductive Language:
  - Datalog

1. Introduction – Languages

- Can current SQL express all Datalog can do?
  - No:
    - Non-linear recursive queries
    - Mutual recursive views
    - Recursion limitations
- Can usual Datalog express all SQL can do?
  - No:
    - Duplicates
    - Nulls

1. Introduction

- Overcoming Datalog Theoretical Expressiveness Limitations:
  - Well, simply let’s add those absent features
  - LDL++ includes a limited form of duplicates
  - DES includes both unrestricted duplicates and nulls

1. Introduction

- That’s Ok, but I’m an SQL programmer, don’t bother me with such a logic language
    - But, What if you can use SQL with the power of Datalog?
    - DES does allow it!
    - Even with already available relational databases

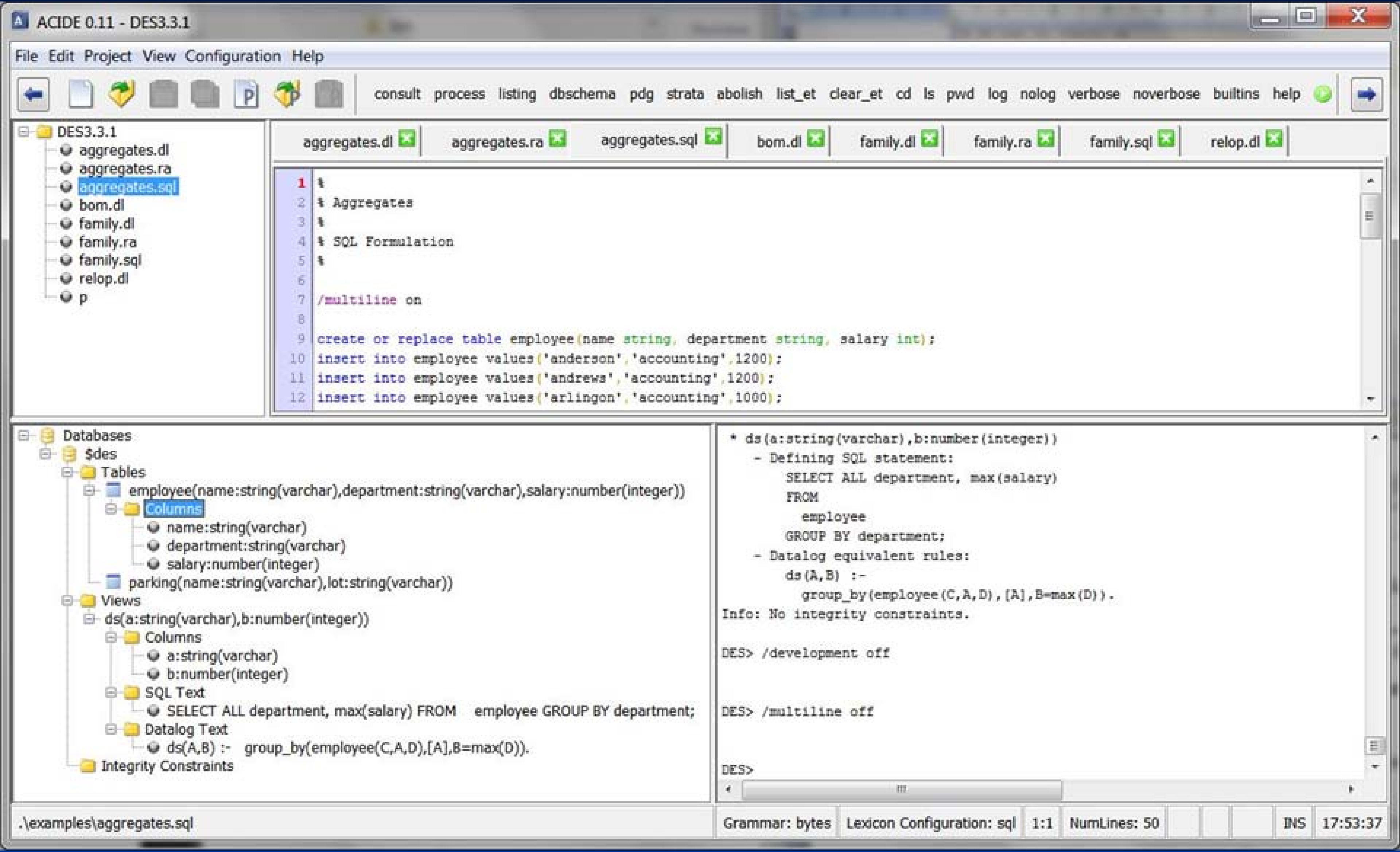
1. Introduction

- Could a major SQL vendor do the same?
- Well, this is the rationale of the proposal, just take it and improve current relational systems!
- But, in the meantime, what could I do?
- Just use database interoperability in DES

2. DES – Datalog Educational System

- Interactive system targeted at teaching databases
- User-friendly (Installation, Usability, >47K downloads)
- Free, Open-source, Multiplatform, Portable
- Query languages sharing EDB/IDB:
  - Datalog following ISO Prolog standard
  - (Recursive) SQL following ANSI/ISO standard
  - (Extended) Relational Algebra
- Null value support *à la* SQL
- Outer joins for RA, SQL and Datalog
- Duplicates
- Aggregates
- Stratified negation ... and many more
- **`des.sourceforge.net`**

DES running under ACIDE



- DES3.3.1
  - aggregates.dl
  - aggregates.ra
  - aggregates.sql
  - bom.dl
  - family.dl
  - family.ra
  - family.sql
  - relop.dl
  - p

```
%
% Aggregates
%
% SQL Formulation
%

/multiline on

create or replace table employee(name string, department string, salary int);
insert into employee values('anderson','accounting',1200);
insert into employee values('andrews','accounting',1200);
insert into employee values('arlingon','accounting',1000);
```

- Databases
  - $des
    - Tables
      - employee(name:string(varchar),department:string(varchar),salary:number(integer))
        - Columns
          - name:string(varchar)
          - department:string(varchar)
          - salary:number(integer)
      - parking(name:string(varchar),lot:string(varchar))
    - Views
      - ds(a:string(varchar),b:number(integer))
        - Columns
          - a:string(varchar)
          - b:number(integer)
        - SQL Text
          - SELECT ALL department, max(salary) FROM employee GROUP BY department;
        - Datalog Text
          - ds(A,B) :- group_by(employee(C,A,D),[A],B=max(D)).
    - Integrity Constraints

```
* ds(a:string(varchar),b:number(integer))
   - Defining SQL statement:
       SELECT ALL department, max(salary)
       FROM
         employee
       GROUP BY department;
   - Datalog equivalent rules:
       ds(A,B) :-
         group_by(employee(C,A,D),[A],B=max(D)).
Info: No integrity constraints.

DES> /development off


DES> /multiline off


DES>
```

.\examples\aggregates.sql

Grammar: bytes

Lexicon Configuration: sql

1:1

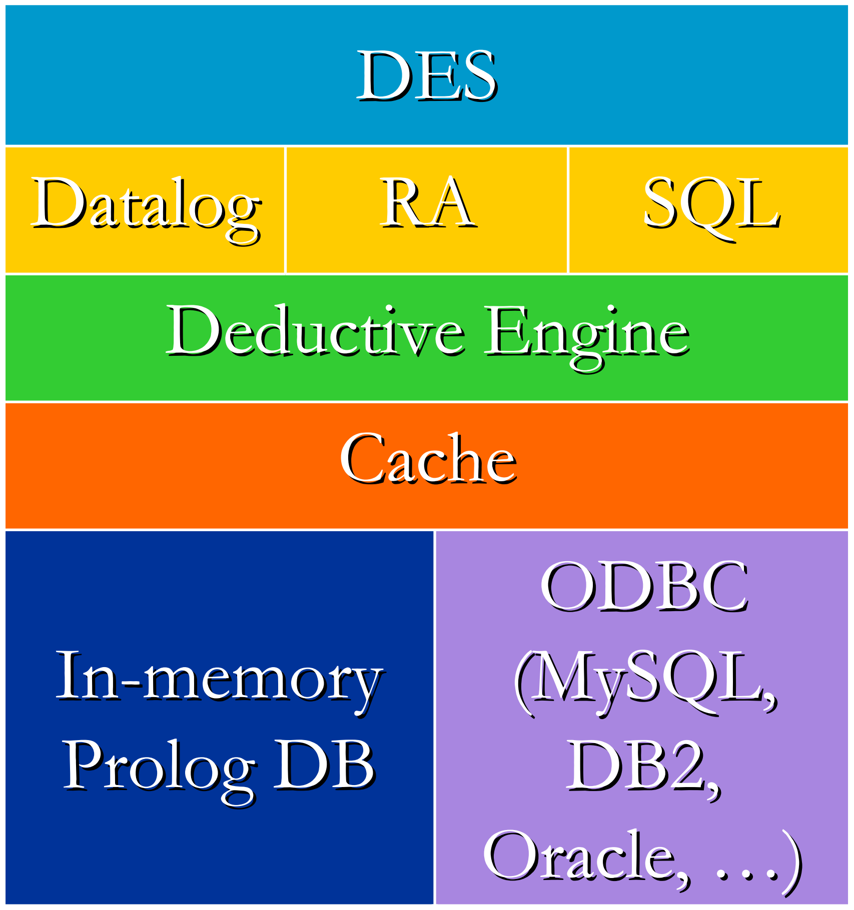
NumLines: 50

INS

17:53:37

3. Enabling Interoperability

- Architecture
- Interoperability
  - In-memory Deductive DB
  - In-memory SQL DB
  - External DB's via ODBC
  - Persistent predicates



DES

Datalog RA SQL

Deductive Engine

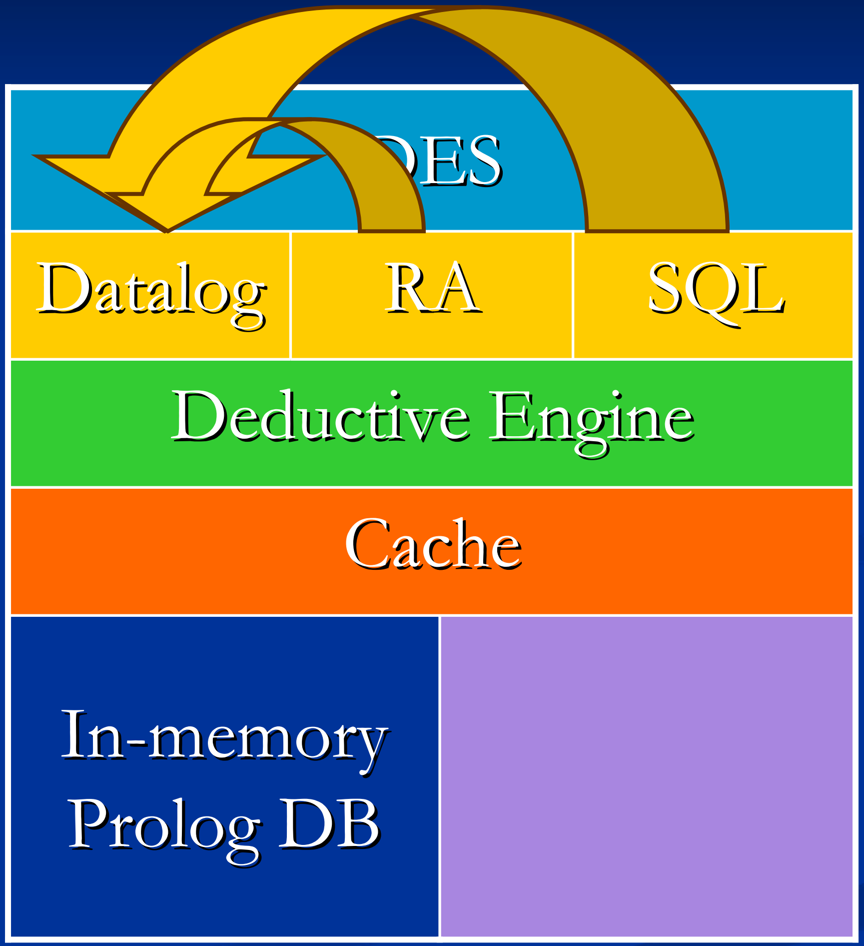
Cache

In-memory Prolog DB

ODBC (MySQL, DB2, Oracle, …)

3.1. In-Memory Database

- Datalog:
  - Relations (Data)
  - Schema (Type assertions)
- SQL:
  - Tables, Views
  - Schema (DDL statements)
- RA:
  - Views
- Deductive database sharing
  - Datalog queries ↔ SQL / RA queries
  - Datalog typed relations ↔ SQL tables and views



DES

Datalog

RA

SQL

Deductive Engine

Cache

In-memory Prolog DB

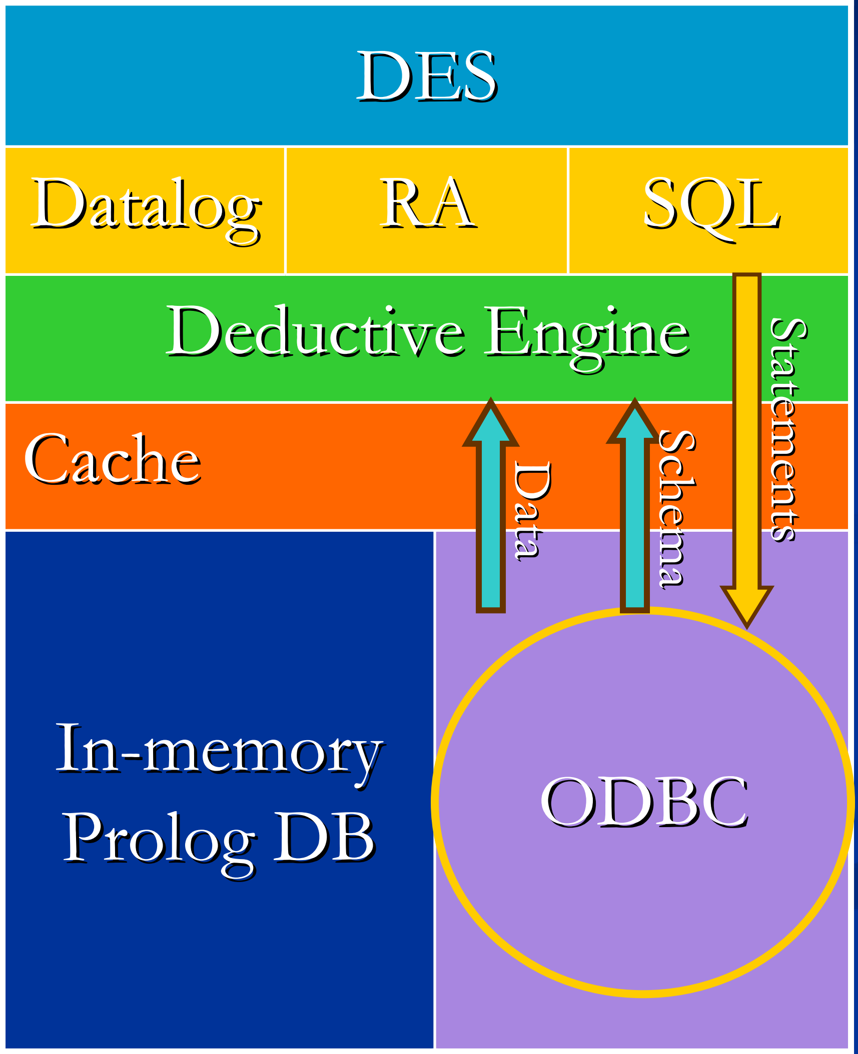
3.1. In-Memory Database

Datalog	SQL
`DES> :-type(employee(name: varchar, dept:varchar, salary:integer)).` `DES> :-pk(employee,[name]).`	`DES> create table employee(name varchar primary key, dept varchar, salary integer);`
`DES> /assert employee(’Smith’,’Sales’,15000).`	`DES> insert into employee values(’Smith’,’Sales’,15000);`

`DES> employee(N,D,S), S>10000.`
`{`
`employee(’Smith’,’Sales’,15000)`
`}`
	`DES> select * from employee where salary > 10000;`
	`answer(employee.name:string(varchar),employee.dept:string(varchar),employee.salary:number(integer)) ->`
	`{`
	`answer(’Smith’,’Sales’,15000)`
	`}`

3.2. Connecting to External DBs

- SQL Statements are issued to the open ODBC connection
- Both data and schema can be retrieved from the external DB
- Existing tables and views in the external DB are visible to the deductive engine



3.2. Connecting to External DBs

```
DES> /open_db mysql
```

External DB

```
DES> create table manager(mgr varchar(10), emp
varchar(10));

DES> insert into manager values (’E1’, ’E2’),
(’E2’, ’E3’), (’E2’, ’E4’);
```

Deductive Engine

+

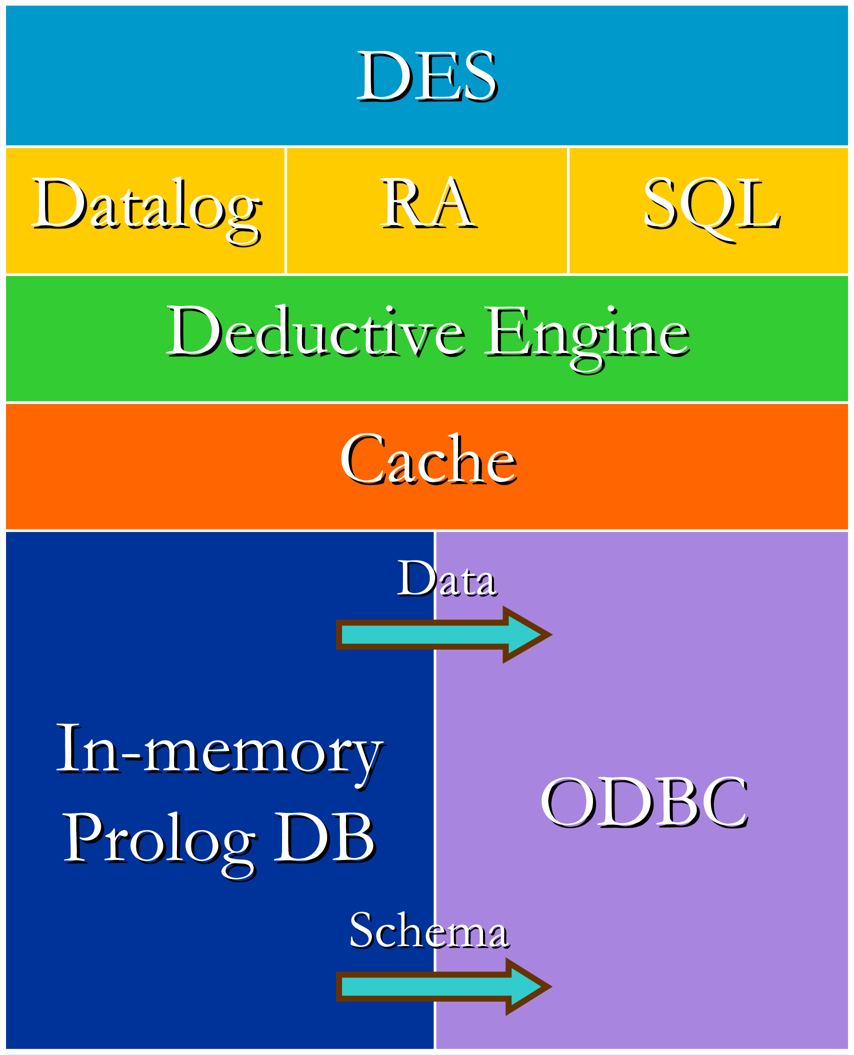
External DB

```
DES> managers(M,E) :- manager(M,E) ;
                      manager(M,M2),managers(M2,E).

{
  managers(’E1’,’E2’), managers(’E1’,’E3’),
  managers(’E1’,’E4’), managers(’E2’,’E3’),
  managers(’E2’,’E4’)
}
```

3.3. Persisting Datalog Predicates

- Durability (ACID Properties) for Deductive Databases
- Given a predicate, it can be made persistent
  - EDB (Facts)
  - IDB (Rules)
  - Schema (Type information)



3.3. Persisting Datalog Predicates

Schema

```
DES> :-type(manager(mgr:string,
                emp:string))
```

EDB
+
IDB

```
DES> /assert manager('E1', 'E2')
DES> /assert manager('E2', 'E3')
DES> /assert manager('E2', 'E4')
DES> /assert managers(M,E) :-
                  manager(M,E) ;
                  manager(M,M2),managers(M2,E).
```

- In-Memory DB

Persist Predicate

```
DES> :-persistent(manager/2,mysql)
```

- External DB

Deductive Engine
+
External DB

```
DES> managers(M,E)
{
  managers('E1','E2'), managers('E1','E3'),
  managers('E1','E4'), managers('E2','E3'),
  managers('E2','E4')
}
```

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4.1. Contrived Formulations

- *Practical Expressiveness*
- Aliases (or, why do we need them?)

```
select * from t, t;  -- Cartesian Product
```

```
select * from t as t1, t as t2;
```

4.1. Contrived Formulations

- Lack of operators

```
select * from s full join q on s.sno=q.sno;
```

```
select * from s left join q on s.sno=q.sno
union all
select * from s right join q on s.sno=q.sno;
```

4.1. Contrived Formulations

- Syntax Restrictions (e.g., nesting)

```
select * from s left join
(select * from q right join sp on
  q.sno=sp.sno where q.qname<sp.pname)
on s.sno=q.sno where s.name=q.qname;
```

4.2. Recursive SQL

Practical and Theoretical Expressiveness

- Linear recursion. Precludes:
  - Fibonacci and the like
  - Graph algorithms
- Acyclic graphs
- No EXCEPT
- No DISTINCT
- UNION ALL
- No aggregates
  - Minimal paths
  - Bound limits

4.2. Recursive SQL

```
with recursive path(ori,des) as
(select edge.*,1 from edge
union all
select path.ori,edge.des from path,edge
  where path.des=edge.ori)
select * from path;
```

```
path(Ori,Des) :-
    edge(Ori,Des)
    ;
    edge(Ori,Int), path(Int,Des).
```

4.2. Recursive SQL

```
create view path(ori,des) as
select edge.* from edge
union
select path.ori,edge.des from path,edge
  where path.des=edge.ori;
```

```
create view path(ori,des) as
with recursive rec_path as
(select edge.* from edge
union all
select rec_path.ori,edge.des from
  rec_path,edge where rec_path.des=edge.ori)
select * from rec_path;
```

4.2. Recursive SQL

- Unrestricted SQL in External DB:

```
:-persistent(edge(ori:int,des:int),mysql).
:-persistent(path(ori:int,des:int),mysql).

with recursive path(ori, des) as
select * from edge
union
select p1.ori,p2.des from path p1, path p2
  where p1.des=p2.ori
select * from path;
```

4.3. The Division RA Operator

```
select sno from
   select sno,pno from spj
   division
   select pno from p where weight=17;
```

```
select distinct sno from spj
except
   select sno from
      (select sno, pno from
         (select sno from spj) as t1,
      (select pno from p where weight=17) as t2
  except
     select sno, pno from spj ) as t3;
```

4.3. The Division RA Operator

- Or simply:

```
v(SNO) :- spj(SNO,PNO,_,_,_) division p(PNO,_,_,17,_)
```

4.4. Functional Dependencies

- $\alpha \longrightarrow \beta$

```
CREATE TABLE emp(name string,
                 zip string,
                 city string determined by zip);
```

- $\{\texttt{zip}\} \longrightarrow \{\texttt{city}\}$

4.5. Hypothetical Queries

- "What-if" queries for decision support systems
- Assuming tuples in EDB
  - SQL

```
assume select 3,1 in edge select * from path;
```

  - Datalog $(\forall x,y(\neg(path(x,y)\leftarrow edge(3,1)))$

```
edge(3,1) => path(X,Y).
```

4.6. Hypothetical Queries

- Assuming tuples in EDB (TC of **edge**):
  - SQL

```
assume
  select e1.ori, e2.des
  from edge e1, edge e2 where e1.des=e2.ori
in edge
  select * from edge;
```

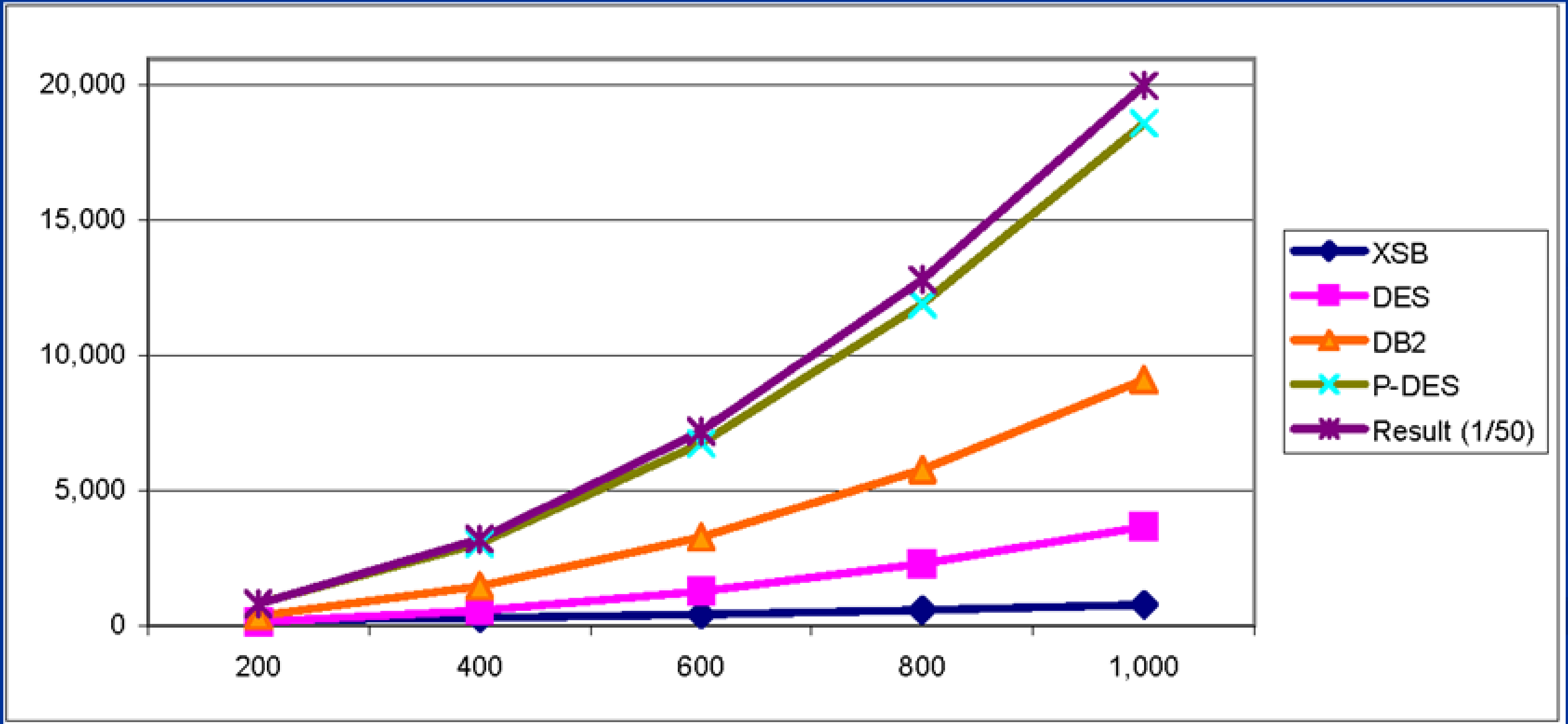
  - Datalog

∀x,y,o,d(¬(edge(x,y)←(edge(o,d)ˇ¬edge(o,i)ˇ¬edge(i,d)))

```
(edge(Ori,Des):-edge(Ori,I),edge(I,Des)) =>
  edge(X,Y)
```

5. Performance

- Cartesian Product (up to 1,000,000 tuples in the result set)



Conclusions

- Datalog vs. SQL. Which is better?
  - Who minds, they both express FOPL (without functions)
  - Give me both, let the user decide
- Is this all new?
  - LDL++ includes duplicates (but not for recursive rules)
  - Some DBMS's include a restricted form of recursion
  - Novel hypothetical queries
- Applications
  - I'd really liked all those nice features when developing for Repsol-YPF, Enagás, ...
- Current DBMS vendors: Please relax SQL limitations!