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
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

```sql
1 2 3
4 SQL Formulation
5
6 /multiline on

7 create or replace table employee(name string, department string, salary int):
8 insert into employee values('anderson', 'accounting', 1200);
9 insert into employee values('andrews', 'accounting', 1200);
10 insert into employee values('arlington', 'accounting', 1000);
```

```
/* ds(a:string(vchar), 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(A, B), [A], B=max(D)).
Info: No integrity constraints.
DES> /development off
DES> /multiline off
DES> 
```

```
\examples\aggregates.sql
```

```

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3. Enabling Interoperability

- **Architecture**
  - DES
  - Datalog
  - RA
  - SQL
  - Deductive Engine
  - Cache
  - In-memory
  - Prolog DB
  - ODBC (MySQL, DB2, Oracle, …)

- **Interoperability**
  - In-memory Deductive DB
  - In-memory SQL DB
  - External DB’s via ODBC
  - Persistent predicates
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
### 3.1. In-Memory Database

<table>
<thead>
<tr>
<th>Datalog</th>
<th>SQL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES&gt; :-type(employee(name: varchar, dept:varchar, salary:integer)).</td>
<td>DES&gt; create table employee(name varchar primary key, dept varchar, salary integer);</td>
</tr>
<tr>
<td>DES&gt; :-pk(employee,[name]).</td>
<td>DES&gt; insert into employee values('Smith','Sales',15000);</td>
</tr>
<tr>
<td>DES&gt; /assert employee('Smith','Sales',15000).</td>
<td>DES&gt; select * from employee where salary &gt; 10000;</td>
</tr>
<tr>
<td>DES&gt; employee(N,D,S), S&gt;10000. {</td>
<td>answer(employee.name:string(name),employee.dept: string(varchar),employee.salary: number(integer)) -&gt;</td>
</tr>
<tr>
<td>employee('Smith','Sales',15000) }</td>
<td>{</td>
</tr>
<tr>
<td></td>
<td>answer('Smith','Sales',15000) }</td>
</tr>
</tbody>
</table>
**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.

![Diagram showing the connection process](image)
### 3.2. Connecting to External DBs

#### External DB

DES> `/open_db mysql`

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

<table>
<thead>
<tr>
<th><strong>Schema</strong></th>
<th>DES&gt; :-type(manager(mgr:string, emp:string))</th>
</tr>
</thead>
</table>
| **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). |
| **Persist Predicate** | DES> :-persistent(manager/2,mysql) |
| **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

```sql
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)

```sql
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
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).
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:

\[ v(SNO) \leftarrow \text{spj}(SNO, PNO, __, __, __) \text{ division } p(PNO, __, __, 17, __) \]
4.4. Functional Dependencies

\[ \alpha \rightarrow \beta \]

CREATE TABLE emp (name string,
   zip string,
   city string \textit{determined by} zip);

\[ \{\text{zip}\} \rightarrow \{\text{city}\} \]
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
    
    ```
    √x,y(¬(path(x,y)←edge(3,1)))
    ```
    
    ```
    edge(3,1) => path(X,Y).
    ```
4.6. Hypothetical Queries

- Assuming tuples in EDB (TC of \textit{edge}): 
  - \textbf{SQL}

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

  - \textbf{Datalog}

  \[
  \forall x,y,o,d (\neg (\text{edge}(x,y) \leftarrow (\text{edge}(o,d) \neg \text{edge}(o,i) \neg \text{edge}(i,d))))
  \]

  \[
  (\text{edge}(\text{Ori},\text{Des}) : \neg \text{edge}(\text{Ori},I), \text{edge}(I,\text{Des})) \Rightarrow \text{edge}(X,Y)
  \]
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!