Coupling OPTYap with a Database System

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- **OPTYap** is a state-of-the-art system that builds on the high-performance Yap Prolog compiler and combines the power of tabling with support for implicit parallel execution of Prolog goals in shared-memory machines.
  - OPTYap allows tabled evaluation of Prolog goals, which can support the efficient resolution of recursive queries.
  - OPTYap also supports or-parallel execution of Prolog clauses, which is interesting to concurrently evaluate database queries.

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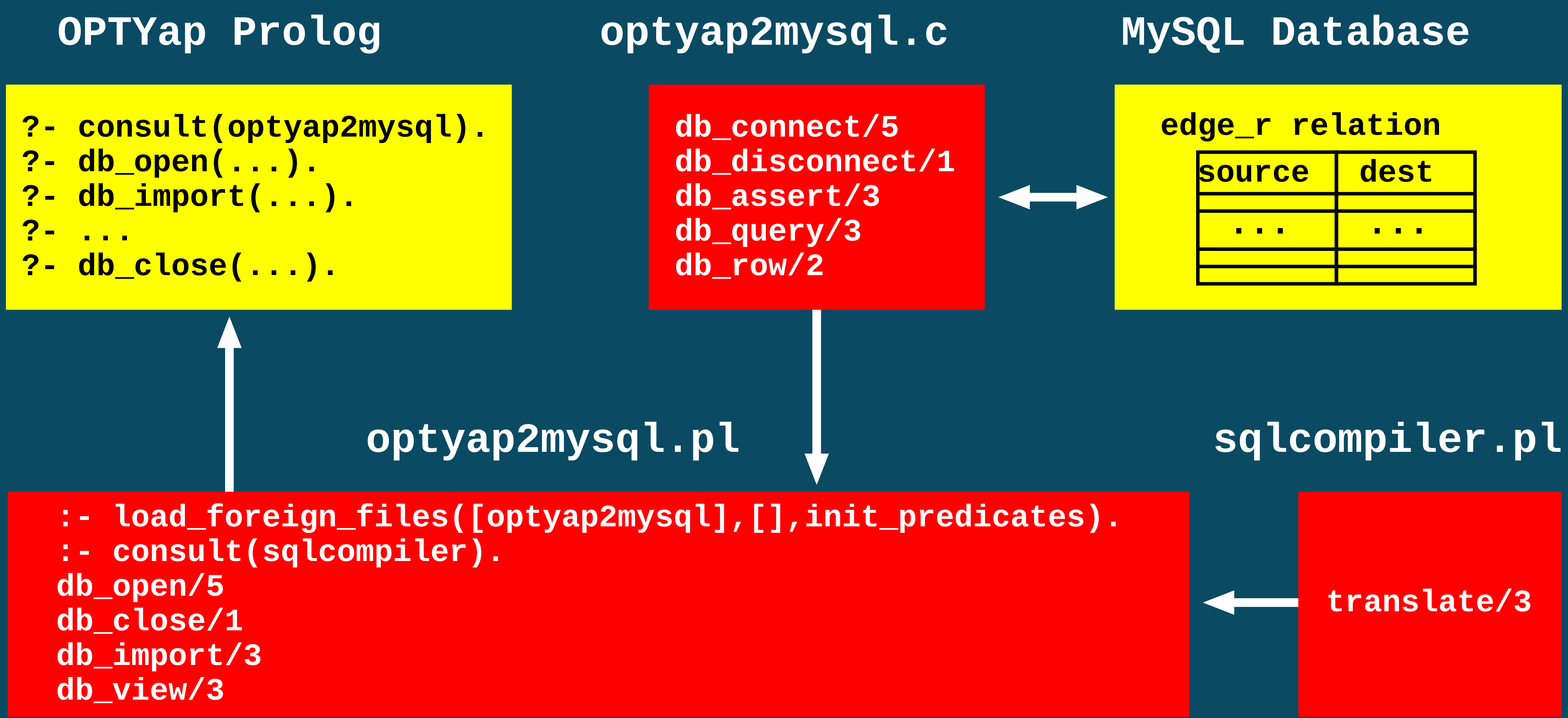
    - OPTYap allows tabled evaluation of Prolog goals, which can support the efficient resolution of recursive queries.
    - OPTYap also supports or-parallel execution of Prolog clauses, which is interesting to concurrently evaluate database queries.
- **MySQL** is a widely used database management system (DBMS), known for its high performance.

Interface between OPTYap and MySQL



- Development tools:
  - Yap Prolog C API
  - MySQL C API
  - Prolog to SQL compiler (Christoph Draxler, 1991)

Accessing Database Tuples Through Backtracking

- When mapping a database relation into a Prolog predicate we use the Yap interface functionality that allows defining **backtrackable predicates**, in such a way that every time the computation backtracks to such predicates, the tuples in the database are fetched **one-at-a-time**.

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- To implement this approach, we **dynamically construct** the clause for the predicate being mapped. For example, if we call db_import(edge_r,edge,my_conn) the following clause is asserted:

```
edge(A,B) :-
   get_value(my_conn,ConnHandler),
   db_query(ConnHandler,'SELECT * FROM edge_r',ResultSet),
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```

- Note that the db_row/2 predicate may fail. For example, if we call edge(1,B), this turns A ground when passed to db_row/2.

Transferring Unification to the Database Engine

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- To implement this approach we use the translate/3 predicate from Draxler's compiler. If we consider the previous example, the following clause will now be asserted.

```
edge(A,B) :-
   get_value(my_conn,ConnHandler),
   translate(proj_term(A,B),edge(A,B),Query),
   db_query(ConnHandler,Query,ResultSet),
   db_row(ResultSet,[A,B]).
```

- When we call edge(1,B), the translate/3 predicate constructs the specific query SELECT 1, dest FROM edge_r WHERE source = 1.

Transferring Unification to the Database Engine

- We can also **transfer the joining process** of more than one database goal to the MySQL engine. Consider, for example, the following predicate and query goal:

```
direct_cycle(A,B) :- edge(A,B), edge(B,A).

?- direct_cycle(A,B).
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- For the first goal, translate/3 generates a query SELECT * FROM edge_r, that will access all tuples sequentially. For the second goal, it gets the bindings of the first goal and generates a query of the form SELECT 1, 2 FROM edge_r WHERE source = 1 AND dest = 2.
- This approach has a substantial overhead of generating, running and storing a SQL query for each tuple of the first goal. To avoid this, we can also benefit from the translate/3 predicate to define **views**.

View-Level Access

- We can define views by using the db_view/3 predicate. For example, if we call db_view((edge(A,B),edge(B,A)),direct_cycle(A,B),my_conn) the following clause is asserted:

```
direct_cycle(A,B) :-
   get_value(my_conn,ConnHandler),
   translate(proj_term(A,B),(edge(A,B),edge(B,A)),Query),
   db_query(ConnHandler,Query,ResultSet),
   db_row(ResultSet,[A,B]).
```

- When later we call direct_cycle(A,B), **only a single query** is generated: SELECT A.source, A.dest FROM edge_r A, edge_r B WHERE B.source = A.dest AND B.dest = A.source.

Using Tabling to Solve Recursive Queries

- Recursive queries can often be **non-terminating** and tend to **recompute the same answers**. Consider, for example, the predicate path/2 that computes the transitive closure of the edge relation.

```
path(A,B) :- edge(A,B).
path(A,B) :- path(A,C), edge(C,B).
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- If we use Prolog standard resolution, a call like path(1,B) will lead to an infinite computation because it calls itself recursively in the second clause.

- On the other hand, the OPTYap tabling mechanism easily detects the recursive call and avoids its re-evaluation. To evaluate a predicate using tabling we simply need to use the table directive.

```
:- table path/2.
path(A,B) :- edge(A,B).
path(A,B) :- path(A,C), edge(C,B).
```

Some Performance Results

Approach/Query	Tuples (Facts)		
	50,000	**100,000**	**500,000**
Prolog Backtracking (*index on first argument*)			
`edge(A,B),fail.`	0.02	0.03	0.16
`edge(A,B),edge(B,A),fail.`	0.54	2.17	10.94
SQL + Backtracking (*primary index on (source)*)			
`edge(A,B),fail`	0.18	0.37	1.95
`edge(A,B),edge(B,A),fail.`	39.88	119.84	1,779.26
`edge(A,B),edge(B,A),fail.` (*view-level*)	6.94	26.18	142.14
SQL + Backtracking (*primary index on (source,dest)*)			
`edge(A,B),fail`	0.22	0.44	2.18
`edge(A,B),edge(B,A),fail.`	23.29	69.81	1,272.81
`edge(A,B),edge(B,A),fail.` (*view-level*)	0.35	0.82	**4.78**

- The MySQL tuple by tuple communication is around 10 times slower
- View-level access introduces significant speed-ups
- Extended indexing capabilities of MySQL can be very useful

Conclusions and Further Work

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  - Accessing and processing result sets from external database systems can cause a significant slowdown when compared with in-memory Prolog facts.
  - In order to be efficient, we need to explore the available indexing schemes of database management systems, together with view-level transformations when accessing the database.

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  - In order to be efficient, we need to explore the available indexing schemes of database management systems, together with view-level transformations when accessing the database.

- Further Work
  - Automatically detect the clauses that contain conjunctions of database predicates and use view-level transformations to generate more efficient code.
  - Further evaluation with more complex queries/applications that can, in particular, explore the or-parallel component of OPTYap.