Combined Tractability of Query Evaluation via Tree Automata and Cycluits
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Problem
Evaluate Datalog queries tractably in parameterized combined complexity

Theorem: Fixed Parameter Tractable
Given a Boolean ICG-Datalog program $P$ of body-size $k_p$ and an instance $I$ of treewidth $k_I$, we can determine if $I$ satisfies $P$ in FPT-linear complexity: $f(k_p, k_I) |P| \cdot |I|$

ICG-Datalog

Intensional Clique-Guarded Datalog: - Fragment of Datalog with stratified negation - Clique-guarded: every intensional atom $S$ is guarded by a clique of extensional atoms $R_i$ $T(x,z) \leftarrow R_1(x,y) \land R_2(y,z) \land R_3(z,x) \land S(x,y,z)$ - Body-size $k_p$: maximal size of a rule

Languages captured
- $\alpha$-acyclic conjunctive queries (CQs)
- CQs of bounded simplicial width
- Guarded negation fragments
- Monadic Datalog of bounded body-size
- Strongly Acyclic 2RPQs

Approach: Through Provenance

Provenance: Boolean function capturing how the query result depends on the input database
Input: A subinstance $J$ of $I$ (with the facts as variables)
Output: Does $J$ satisfies $P$?

Existing representations: formulas, circuits

Cycluits: A New Provenance Representation

Boolean cyclic circuits (cycluits) with stratified negation
Semantics: least fixed-point
Evaluation: linear time
Can be decyclified
Application: Probabilistic Query Evaluation

Proof Structure

ICG-Datalog program $P$ of body-size $\leq k_p$

1. $C(x) \leftarrow \text{Subway(“Corvisart”,} x)$
2. $C(x) \leftarrow C(y) \land \text{Subway(y,} x)$

Two-way Alternating Tree Automaton $A$

Provenance Cycluit

"Under which conditions is it impossible to go from station Corvisart to station Châtelet with the subway?"