Combined Tractability of Query Evaluation via Tree Automata and Cycluits

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Big data, big queries

Conjunctive query Q on relational instance I

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$\rightarrow$ Efficient provenance computation

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- Bounded treewidth data: MSO has $O(|I|)$ time *data* complexity
- Problem: nonelementary in the query $2^{2^{\cdot^{\cdot^{\cdot^{|Q|}}}}}$ (EXPTIME for CQs)

Our Approach

Approach	Restrict $\mathcal{Q}$	Restrict $\mathcal{I}$	
Complexity	linear in combined	linear in data	
Expressivity			

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Best of both worlds!

Parameterized Complexity

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Definition

The problem is *fixed-parameter tractable (FPT) linear* if there exists a computable function f such that it can be solved in time $f(k_I, k_Q) \times |Q| \times |I|$

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3) ... and also **FPT-linear** (combined) computation of provenance

- We design a new concise provenance representation based on cyclic Boolean circuits: ***cycluits***

ICG-Datalog

- Fragment of Datalog with stratified negation

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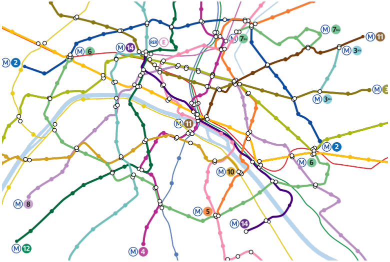
  "*size to write a rule*"
- We also allow stratified negation

Example

Database I

of treewidth ≤ k_I



(Paris Metro map)

ICG-Datalog program P

C(x) ← Subway("Corvisart",x)

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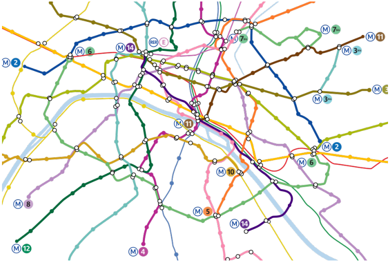

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ICG-Datalog program P

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$$C(x) \leftarrow \text{Subway}(\text{"Corvisart"}, x)$$
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2
$$\text{Goal}() \leftarrow \neg C(\text{"Châtelet"})$$

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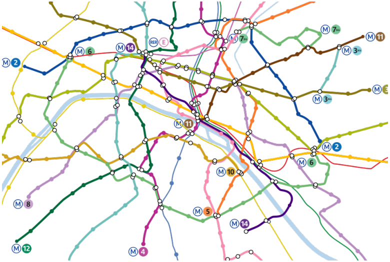

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"Is it impossible to go from station Corvisart to station Châtelet with the subway?"

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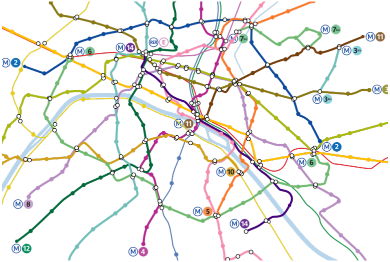

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ICG-Datalog program P
of body-size 4

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CQs captured

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Bounded simplicial width conjunctive queries can be captured by bounded body-size ICG-Datalog programs

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Theorem

Bounded simplicial width conjunctive queries can be captured by bounded body-size ICG-Datalog programs

- Cannot capture bounded treewidth CQs with the same tools

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- Some Guarded Negation fragments (e.g GNF with *CQ-rank*)

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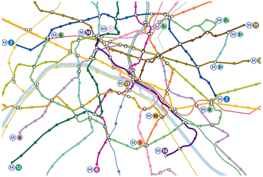

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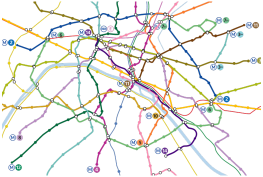

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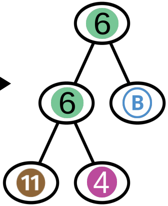
O(g'(k_I) |**I**|)

Tree encoding E



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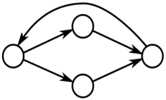

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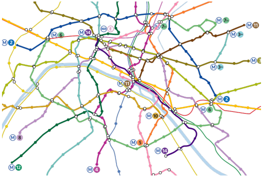

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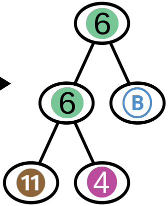

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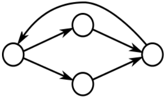

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Answer

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"Is it impossible to go from station Corvisart to station Châtelet with the subway?"

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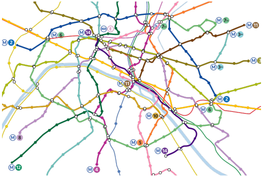

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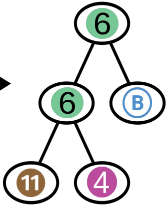

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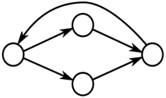
Two-way Alternating Tree Automaton A



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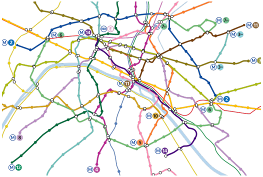

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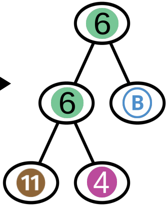

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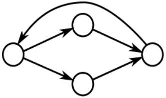

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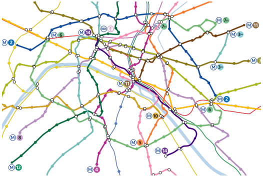

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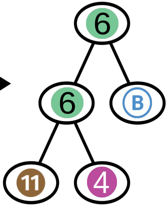

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Theorem

*Given an ICG-Datalog program P with body-size k_P and a relational instance I of treewidth k_I, we can compute in time $f(k_P, k_I) \times |P| \times |I|$ a Boolean **cycluit** capturing $\mathrm{Prov}(Q, I)$*

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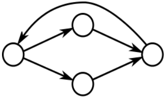

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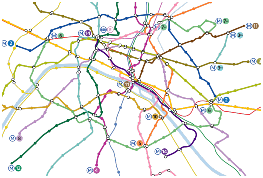

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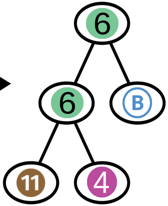

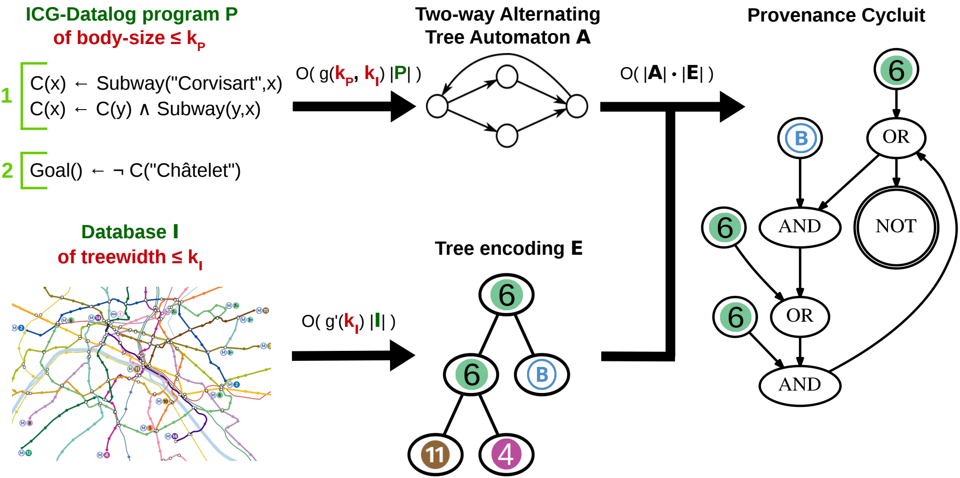

(Paris Metro map)

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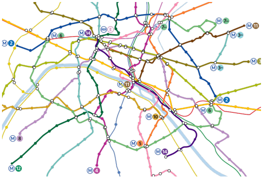

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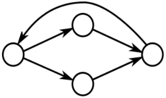
O(g(k_P, k_I) |P|)

O(g'(k_I) |I|)

Two-way Alternating Tree Automaton A



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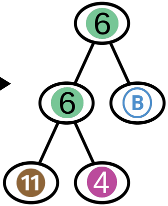

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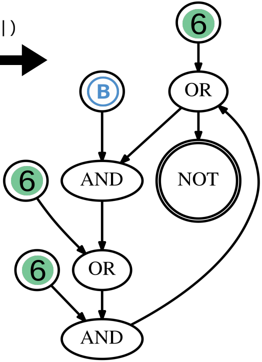
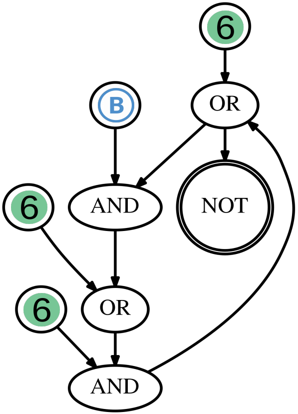
Provenance Cycluit



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

Cycluits



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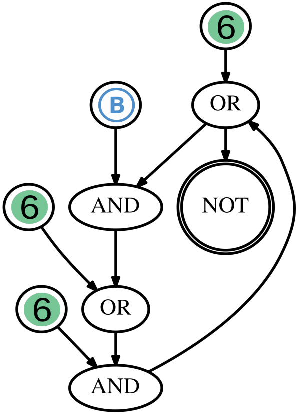

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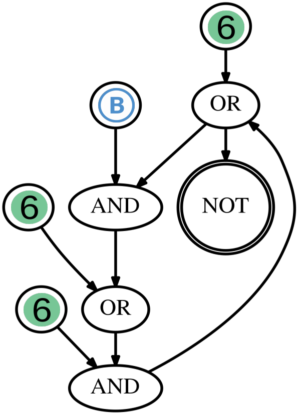

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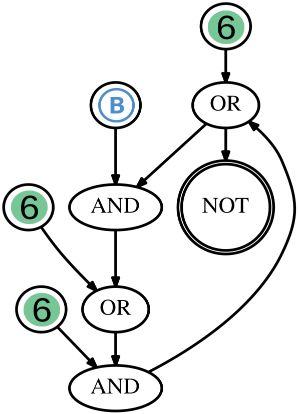

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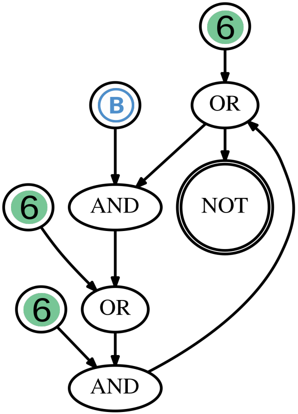

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Thank you!

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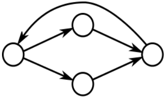

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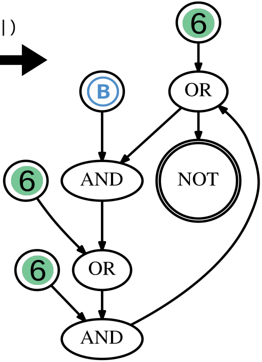

Database I
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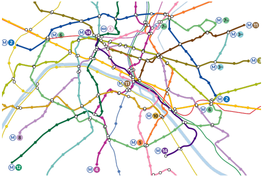

(Paris Metro map)

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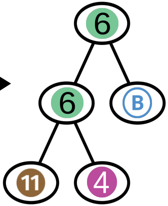

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