

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
 $T(x,z) \leftarrow R_1(x, y) \wedge R_2(y, z) \wedge R_3(z, x) \wedge S(x, y, z)$
- **Body-size k_p** : maximal size of a rule

Languages captured

- α -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



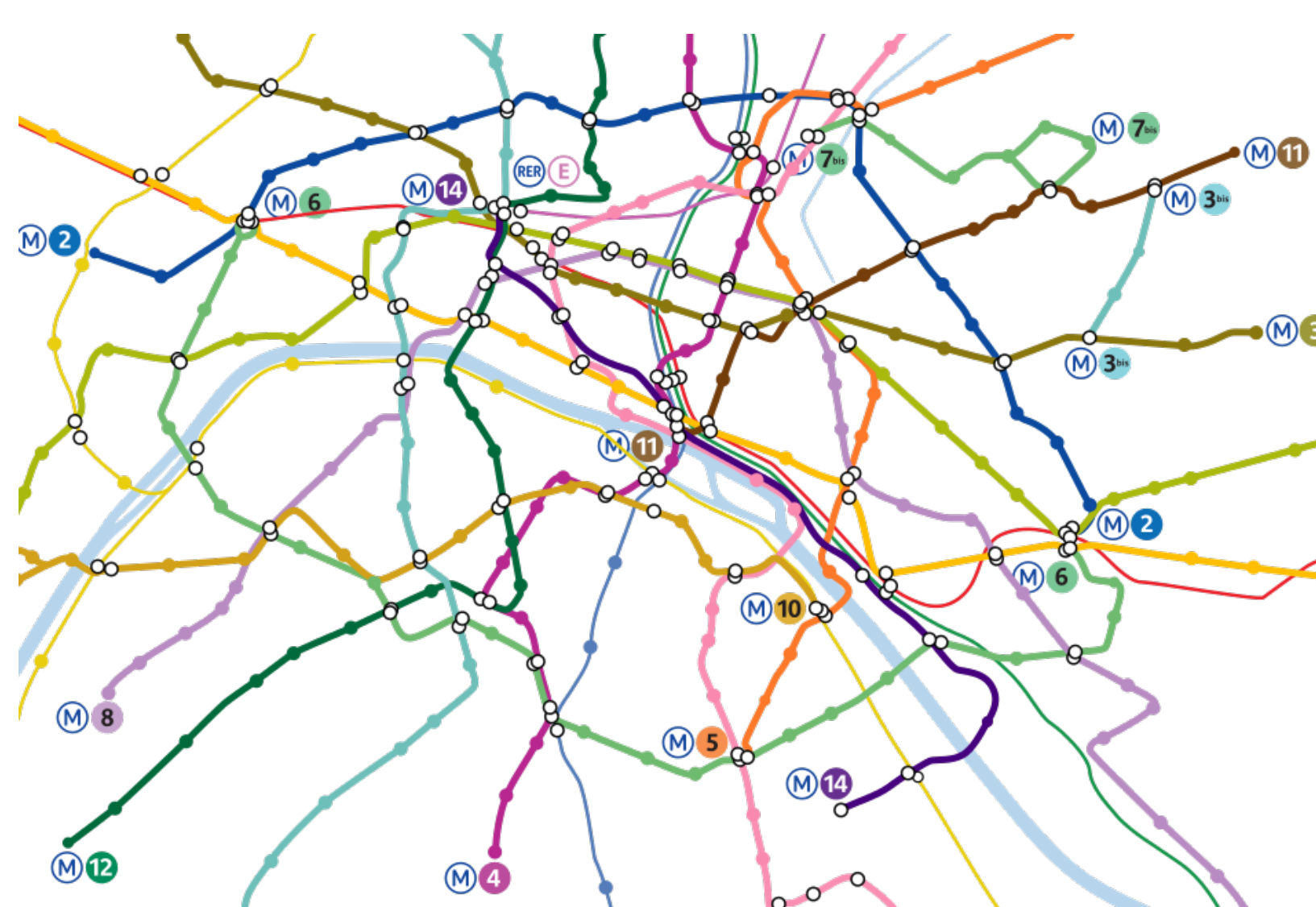
Proof Structure

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

- 1 $C(x) \leftarrow \text{Subway}(\text{"Corvisart"}, x)$
 $C(x) \leftarrow C(y) \wedge \text{Subway}(y, x)$

- 2 $\text{Goal}() \leftarrow \neg C(\text{"Châtelet"})$

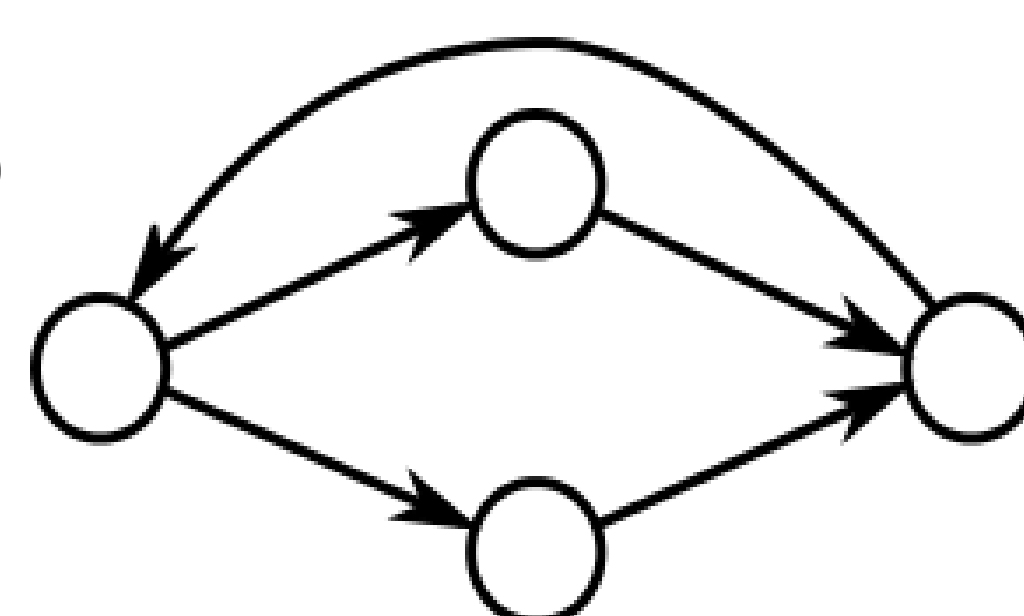
Database I
of **treewidth $\leq k_I$**



(Paris Metro map)

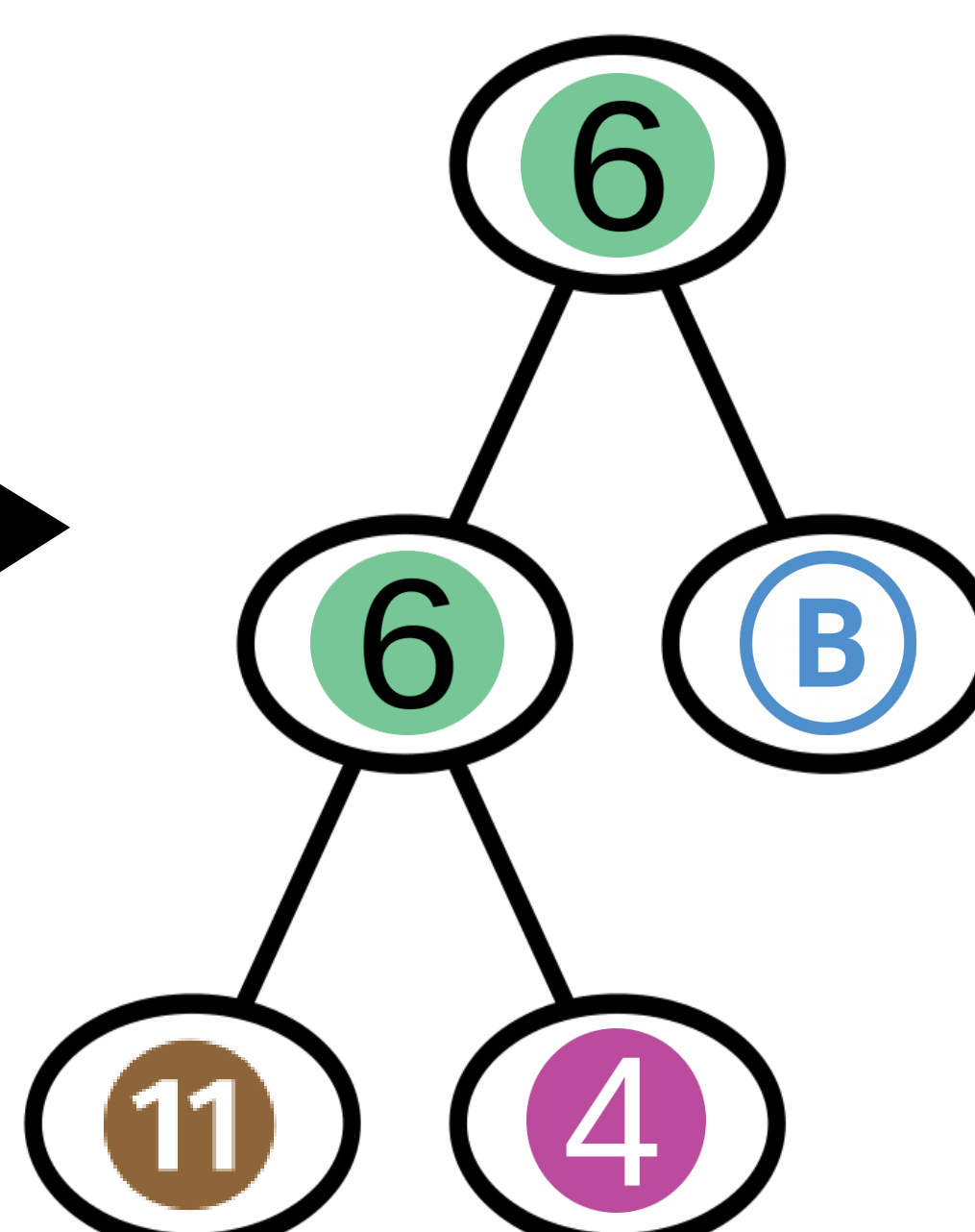
$O(g(k_p, k_I) |P|)$

Two-way Alternating Tree Automaton A



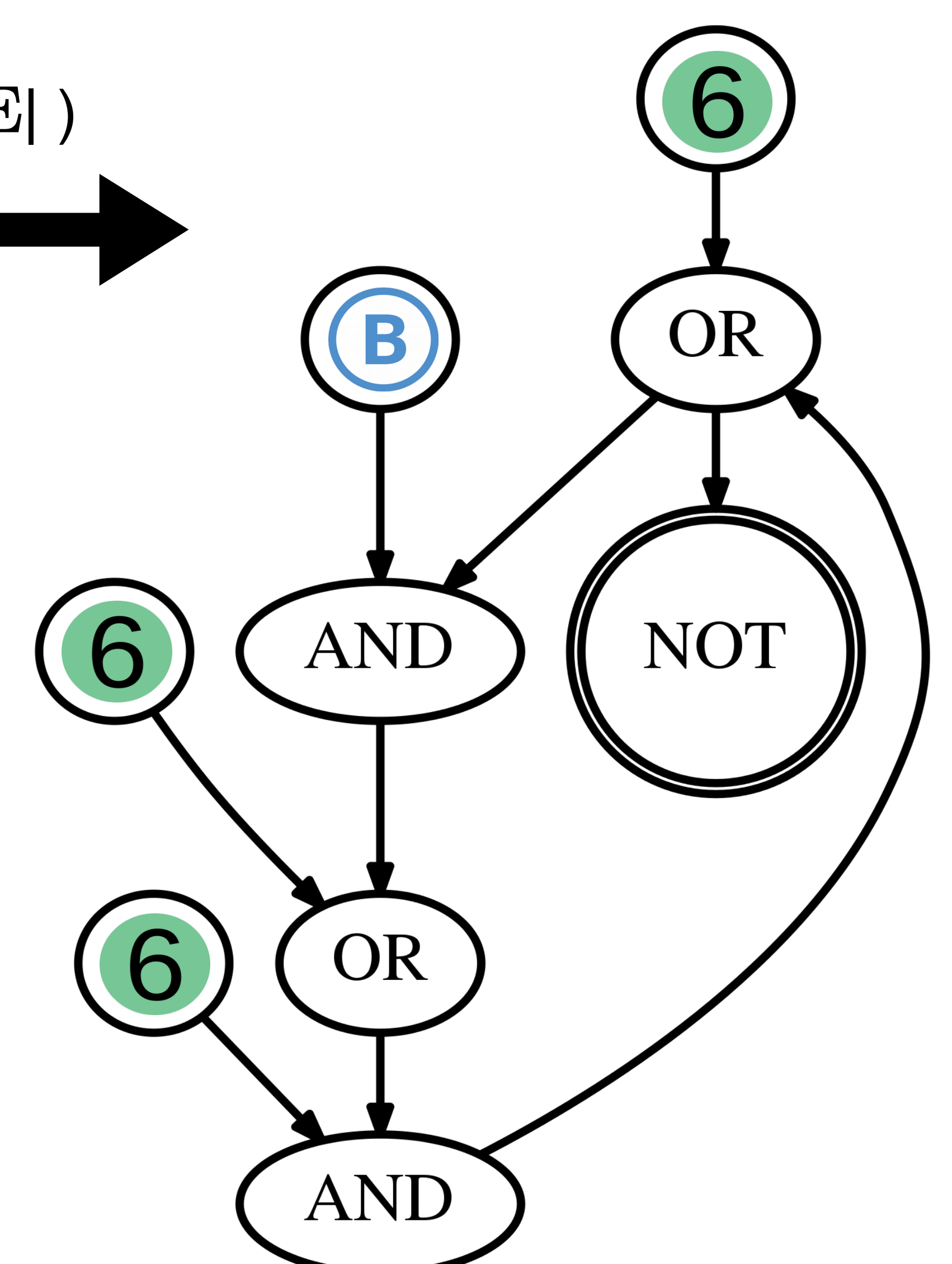
$O(|A| \cdot |E|)$

Tree encoding E



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

Provenance Cycluit



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