FluiDB: Adaptive storage layout using reversible relational operators

<Subtitle>

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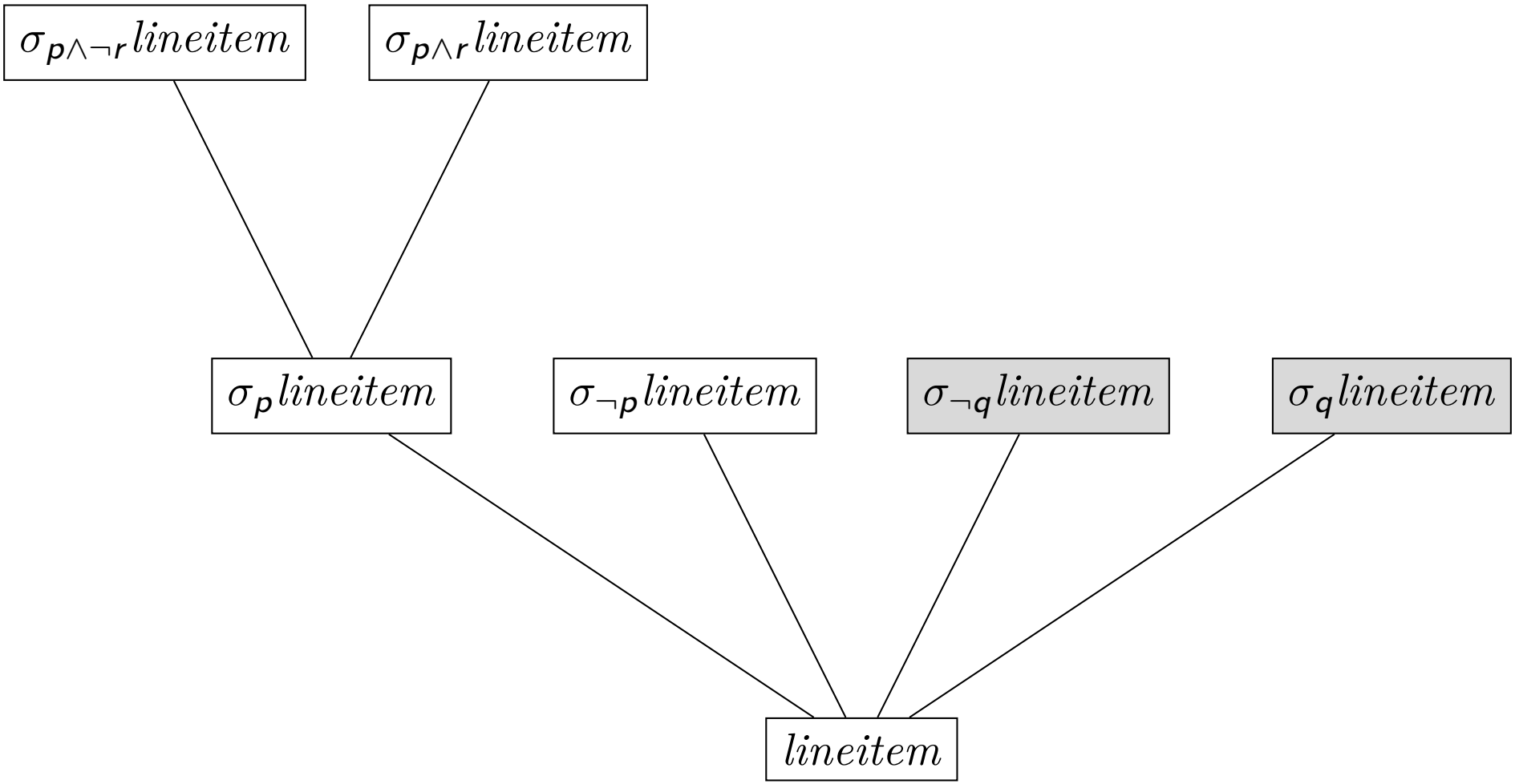
FluiDB at a glance

- FluiDB is an in-memory RDBMS that optimizes data layout for space efficiency w.r.t. the workload
- The main novelty relates to the introduction of reversible relational operations which affords a new perspective on query planning and view selection.
- FluiDB materializes all intermediate results and deletes garbage collects when she runs out of space.

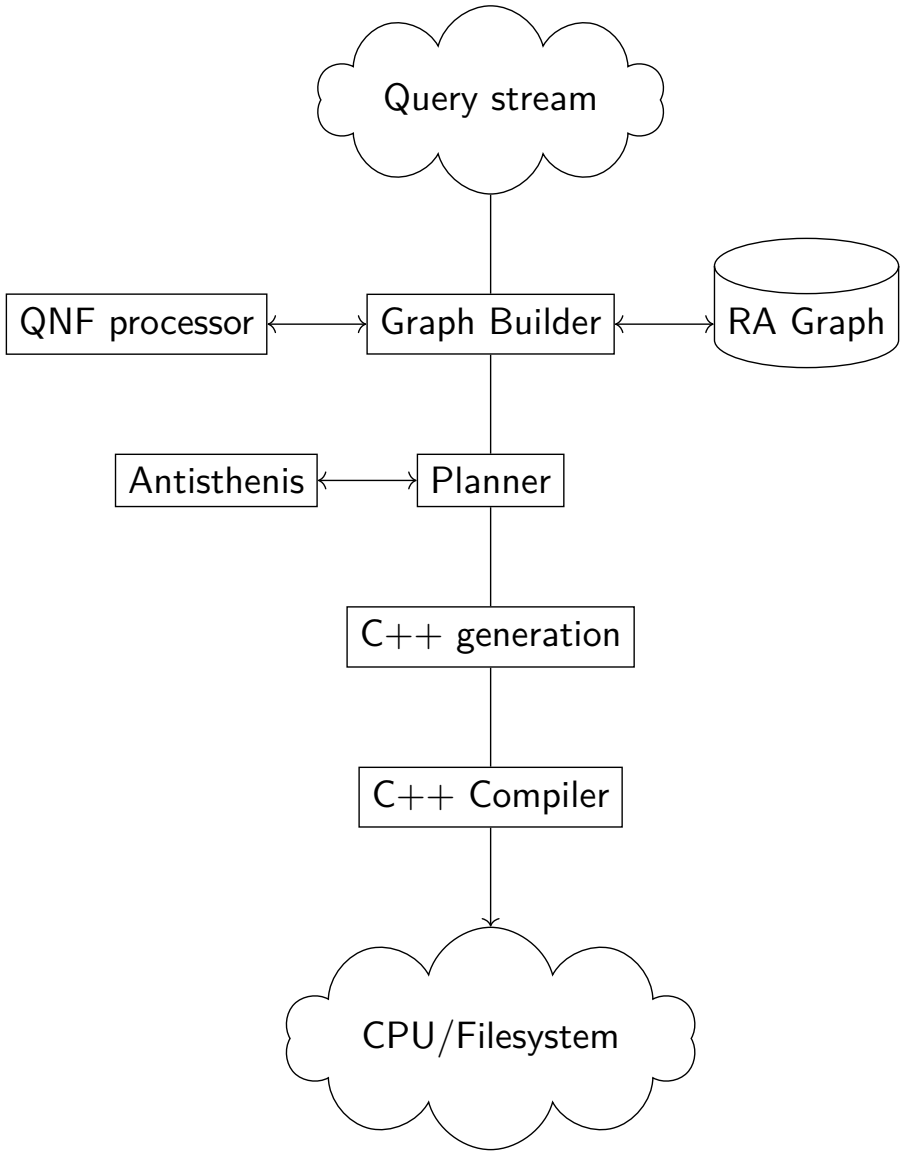
Fundamental principle



The interesting components

- Graph management and query normal form representation
- Logical planning infrastructure
- Antisthenis: An incremental numeric evaluation system for cost estimation.
- Logical planning algorithm and garbage collector
- Code generation system.

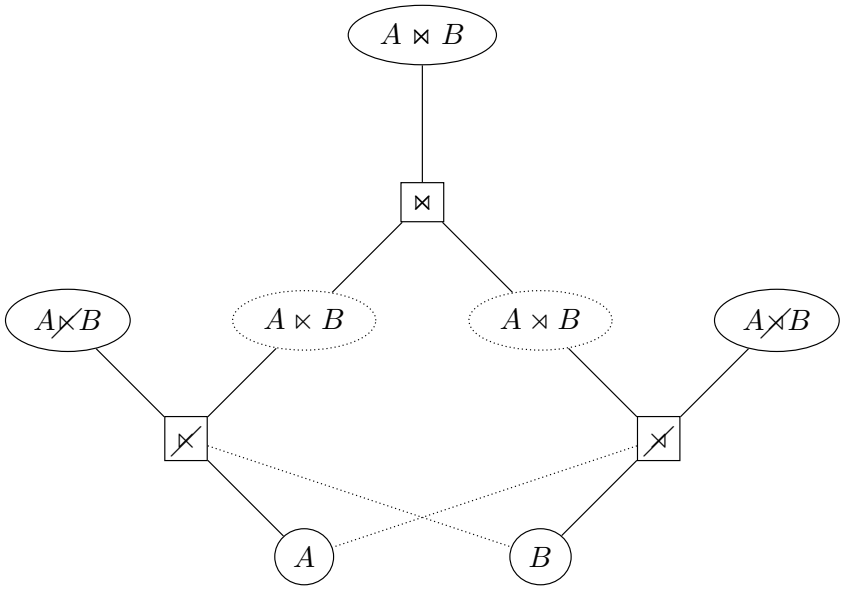
Architecture

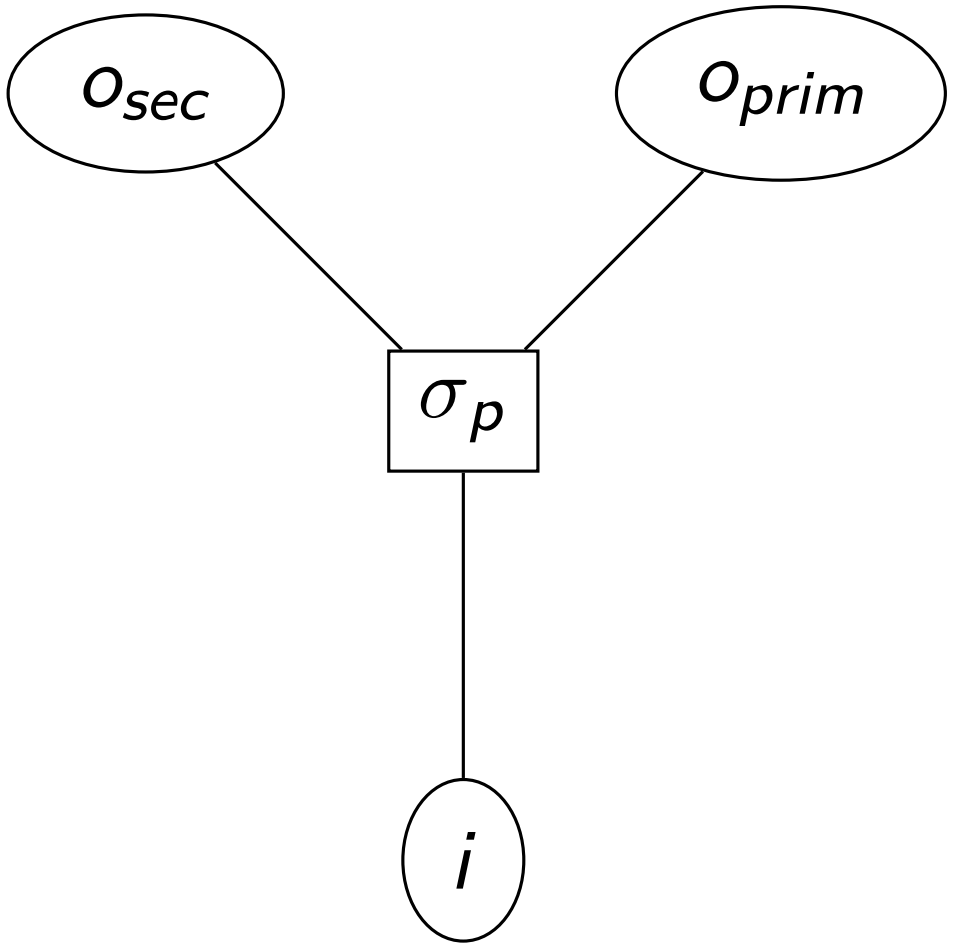


Logical planning

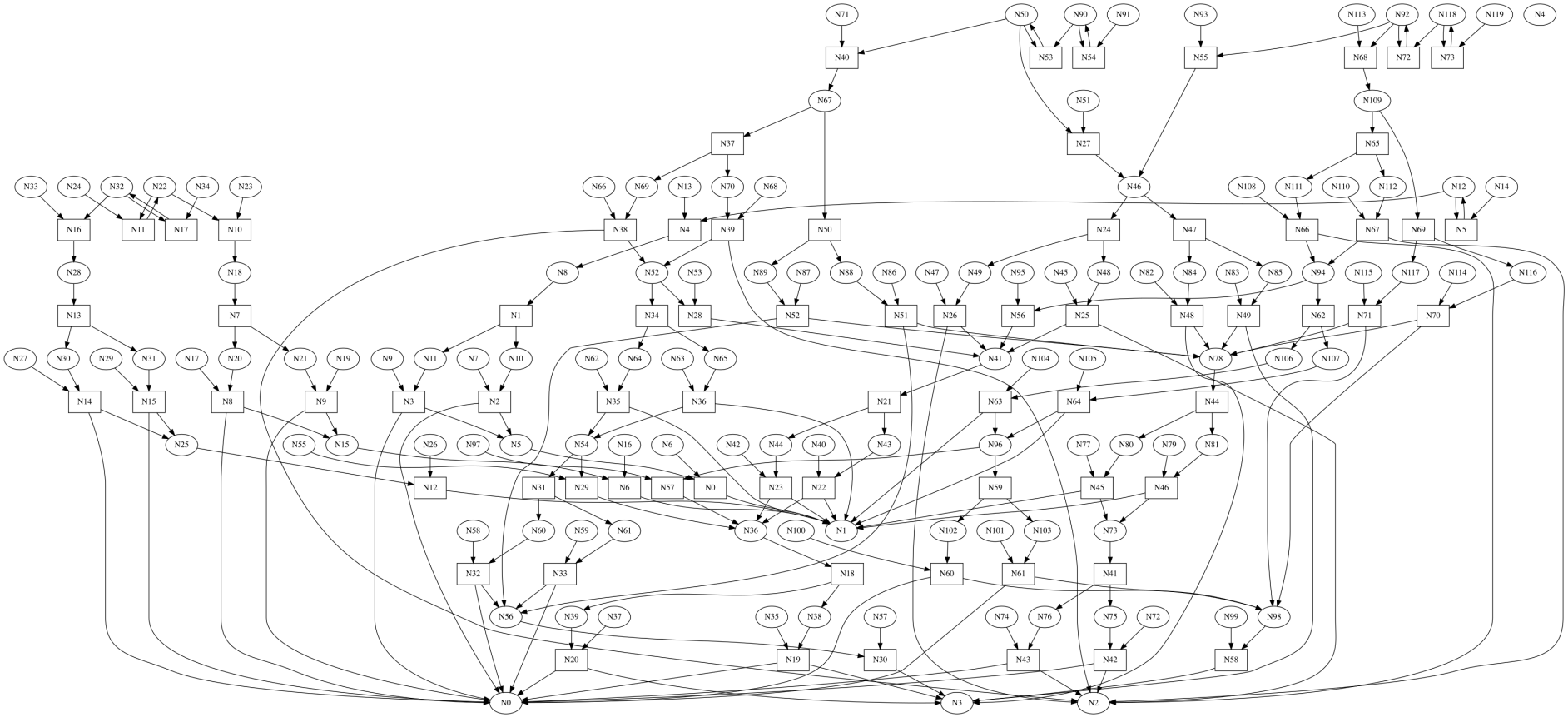
- Bipartite query graph – RA operations/relations unified for all queries
- Join ordering enumeration
- QNF – $\pi\sigma(Q_1 \times Q_2 \times \dots)$ or $\gamma\sigma(Q_1 \times Q_2 \times \dots)$
- Relation shape propagation – cardinality, columns/types, unique subtuples

Reversible operators





Reversible operations



Physical planning

`HCntT` logic monad

Logic framework for "fair" traversal of the plan search space. Intricudes:

- `a <//> b`: Try the rest of the computation with `a` and if it fails try `b`.
- `once c`: try the continuation with values from `c` until one works and stick with that one.
- `halt n`: yield to a scheduler and assigne priority `n` to the continuation.

Physical planning

Business logic

```
materialize n = unless (materialized n) $ do
  op ← inputOps n
  outputs ← possibleOutputs n op
  let inputs = inputsOf op
  -- Assuming we materialized the output, what is the cost of the
  -- outputs
  once (gc outputs)
  histCost ← withMaterialized outputs $ historicalCosts
  -- Stop and schedule this branch according to its cost
  halt (cost op + histCost + anticipatedCost inputs)
  -- Recursively materialize the input relations
  mapM materialize inputs
  registerPlan op
  mapM (setState Materialized) output
```

Antisthenis

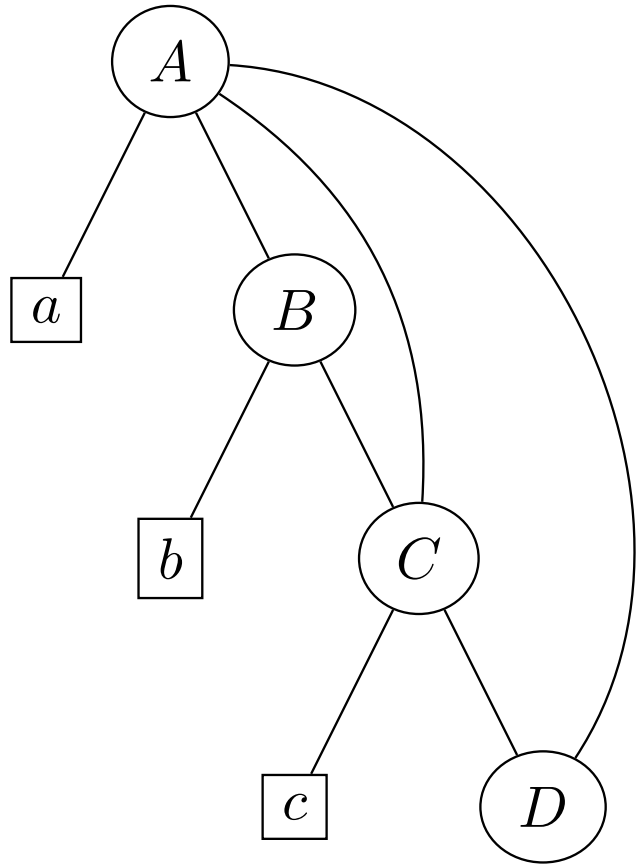
Dynamically scheduled incremental computation

Materializablility and cost inference are numerical operations:

- Input is mostly the same between runs: **incremental**.
- **Order of computation** highly affects the performance (eg absorbig elements, min).
- Self referrential computations may appear earlier than the absorbing element.

Antisthenis: Expression graphs

$$A = a + B + C + D$$
$$B = C \times b$$
$$C = D + c$$
$$D = 0$$



Antisthenis: Absorbing element

$$A = B \times C \times D$$

$$B = \sum_i i$$

$$C = 10 - 10$$

$$D = \sum_i i$$

Antisthenis: Early stopping – recursive expressions

While expressions may be self-referential, we can sometimes still evaluate them.

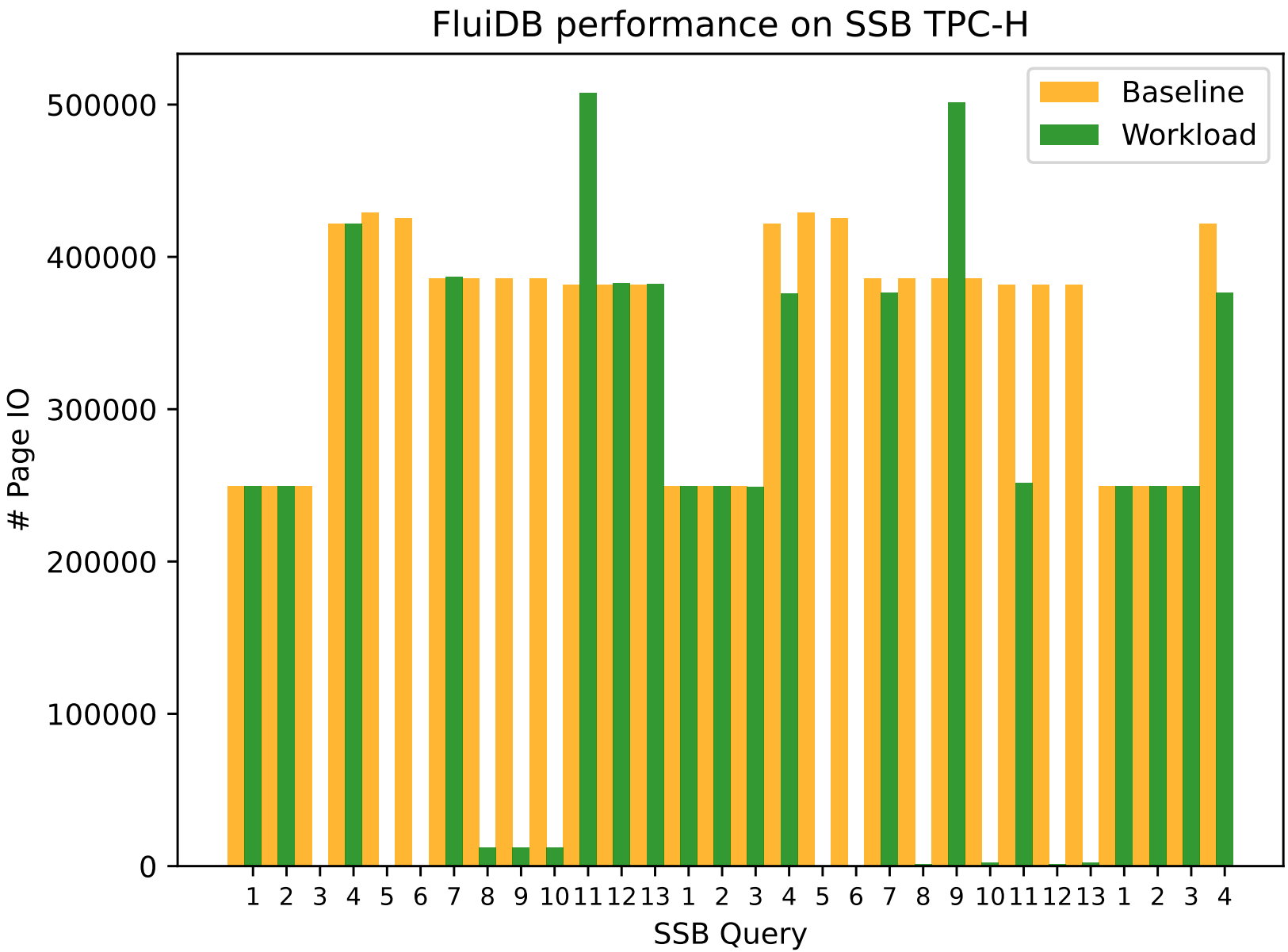
$$A = min(B, C, D)$$
$$B = b_1 + b_2 \cdot D$$
$$C = c_1 + c_2 \cdot A$$
$$D = d_1 + d_2 \cdot B$$

$$b_1 = b_2 = d_1 = d_2 = 1$$
$$c_1 = 3$$
$$c_2 = 0$$

Data layout

Code generation

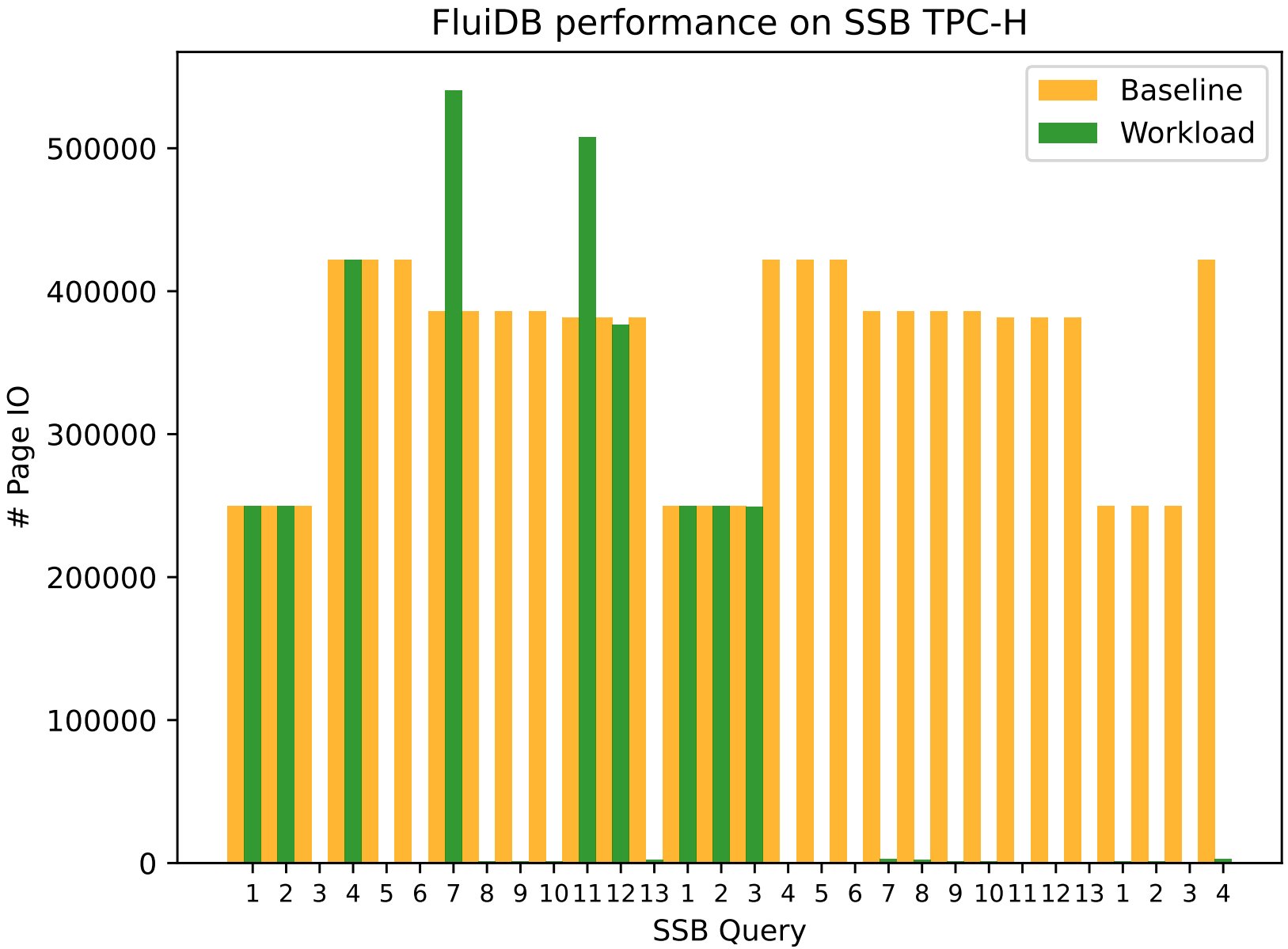
Evaluation: 23K pages budget



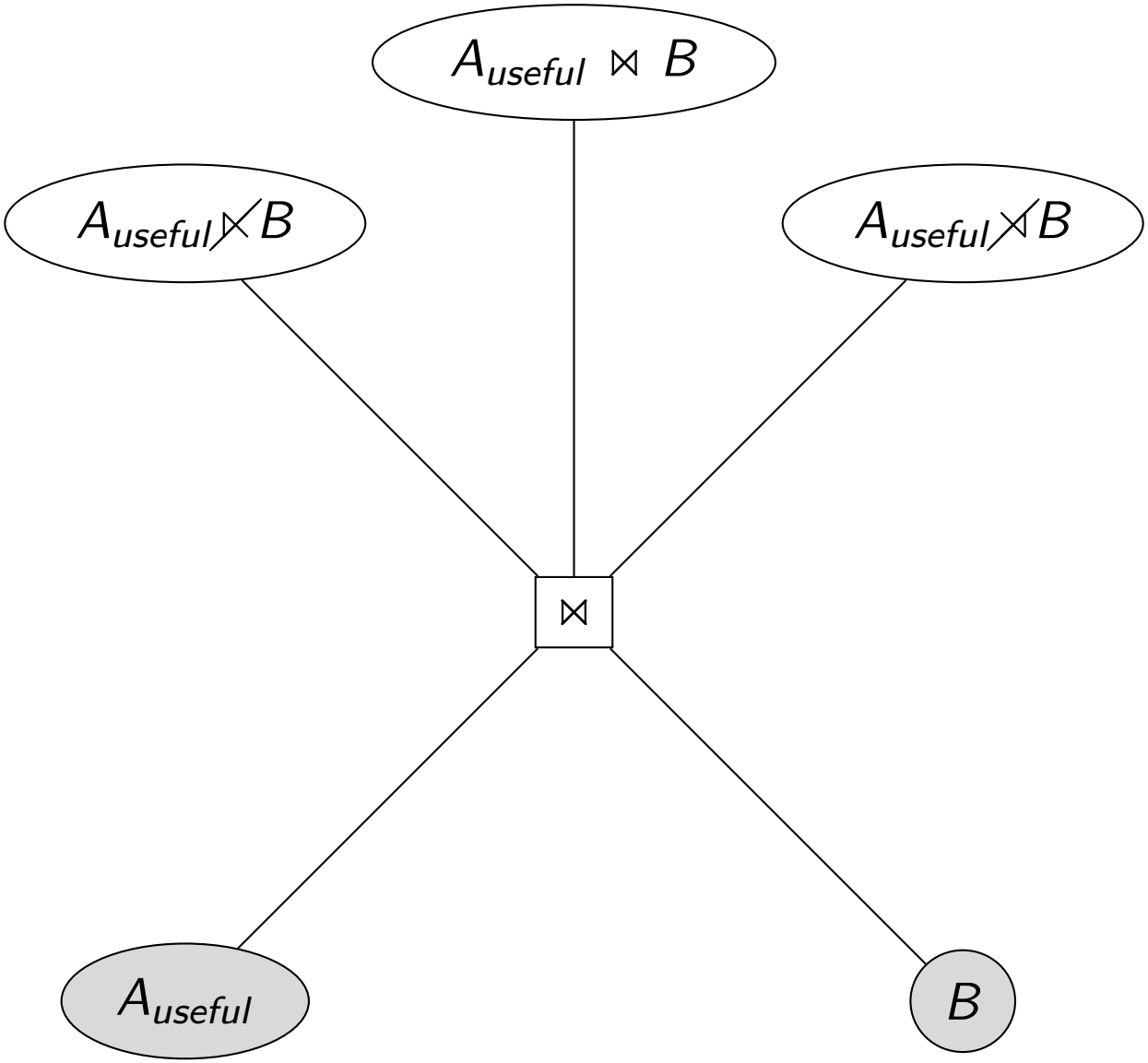
Evaluation: 65K pages budget

Evaluation: But ... 61K pages budget

lineorder is deleted at 6 because all join outputs were materialized



Having enough rope



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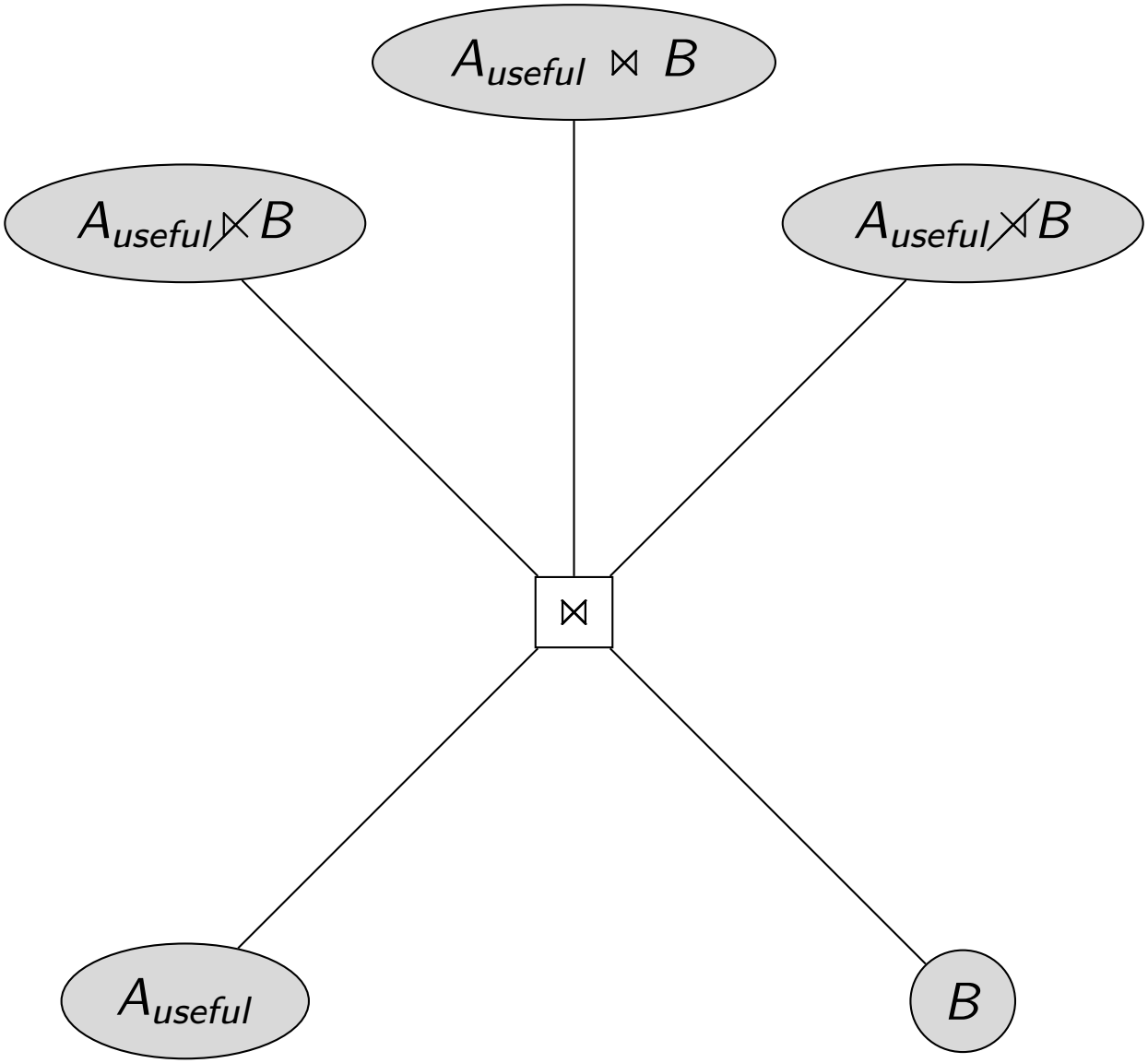

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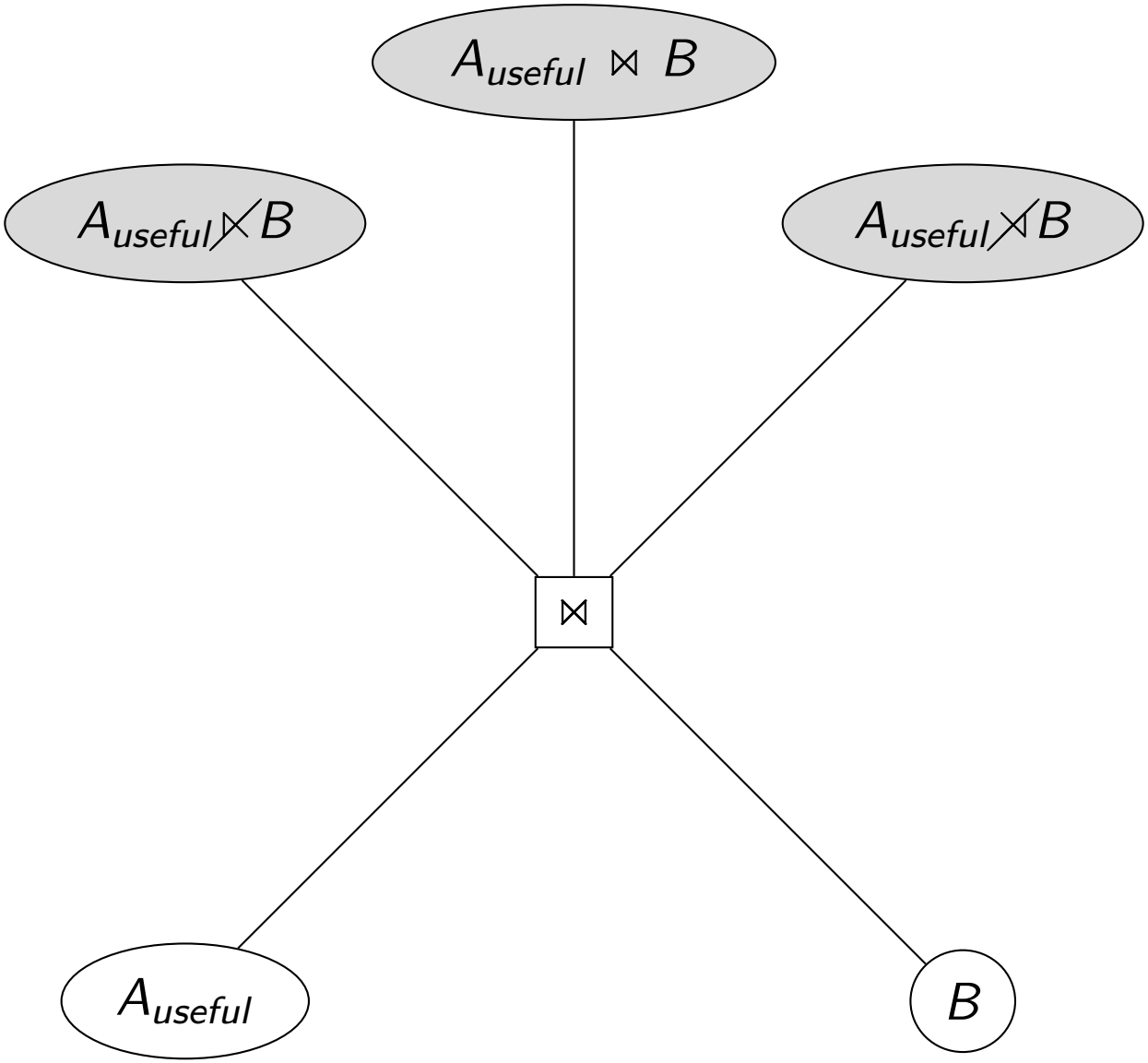

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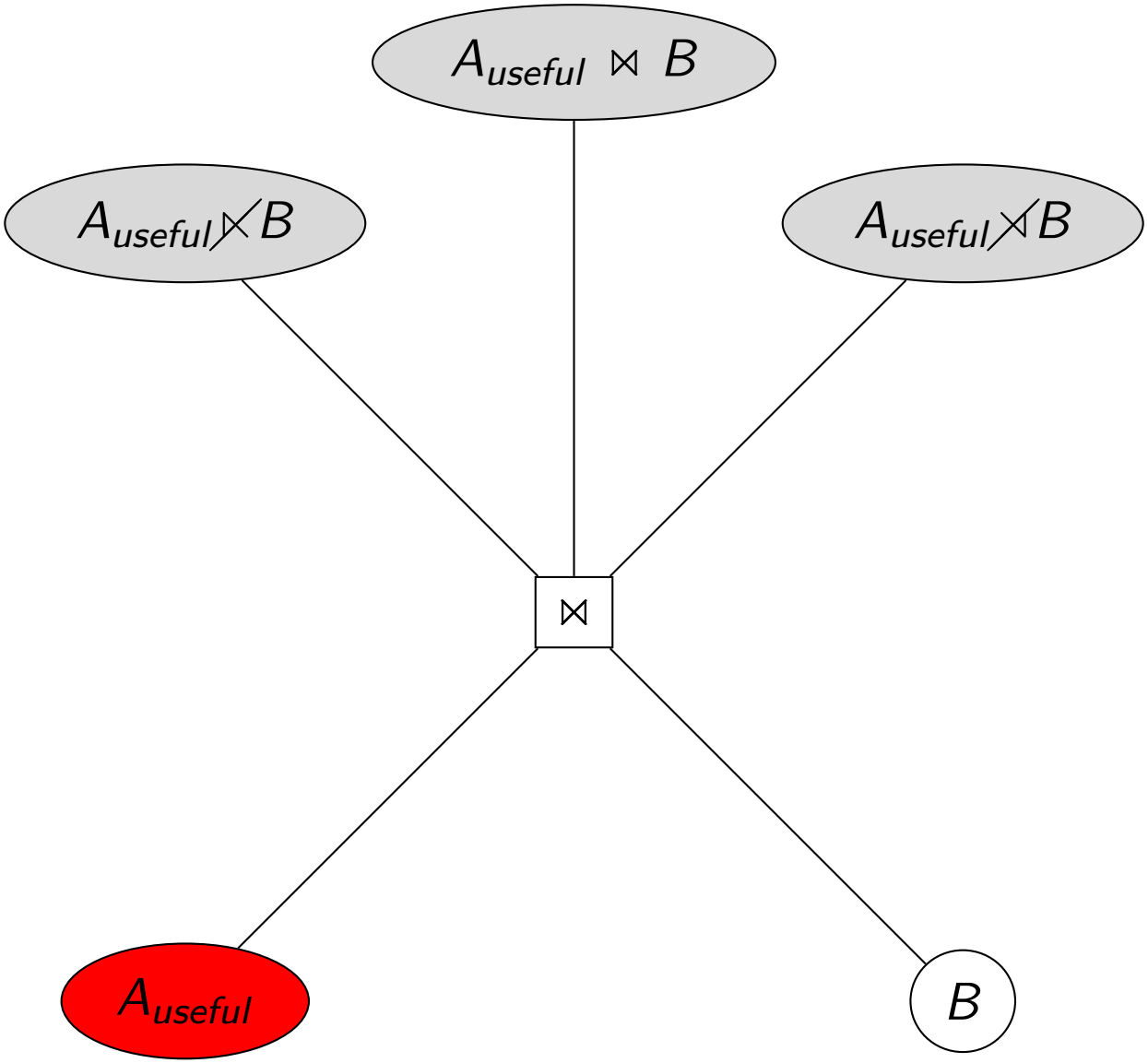

Coclusions and future perspectives

- FluiDB can efficiently use memory budget to store useful intermediate results.
- It would be interesting to:
  - Cardinality estimation is a major pain point for FluiDB, the architecture is accomodating to propagation of statistics
  - Parallel query processing
  - Support updates
  - extend the algebra with index-building operators.
  - Drop the C++ compiler.