On the Performance of Query Optimization Without Cost Functions and Very Simple Cardinality Estimation

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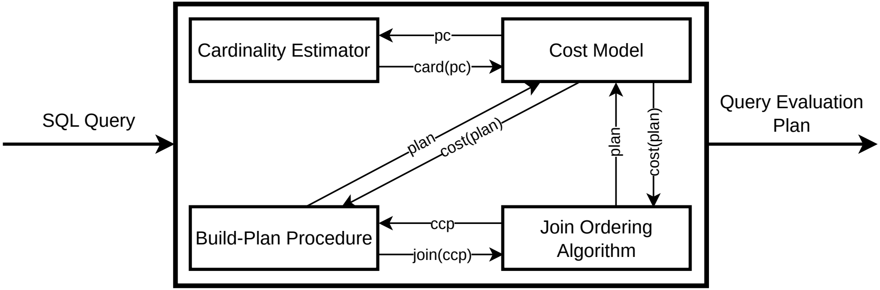
Introduction and Motivation

Modules of a **Database Management System (DBMS)** w.r.t. **Query Optimization (QO)**:



When developing a new DBMS, implementing these requires **compromise**.

Introduction and Motivation

Recent attempts to **query optimization simplification**:

- Hertzschuch et al. (2021)
- Datta et al. (2024)

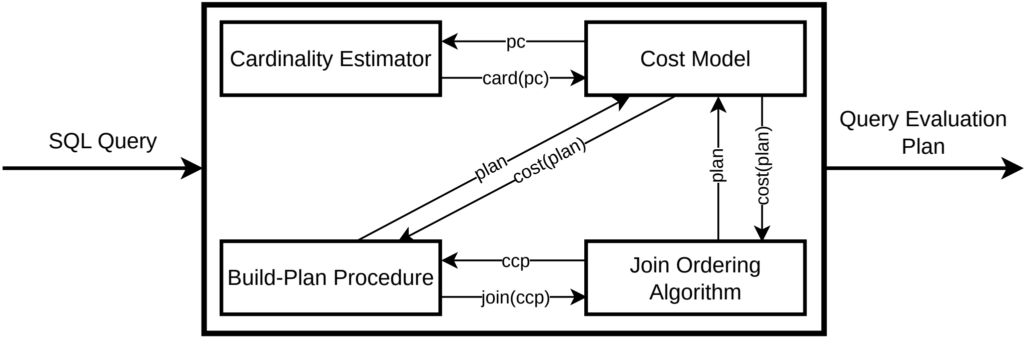
Research Questions

1. How simple can cardinality estimation (CE), cost function (CF), and build-plan procedure (BP) become while still yielding QEPs with an acceptable quality?
2. Can we get acceptable plans even if BP does not use any cost function at all?

Contributions

- Two new simple cardinality estimators: $\mathrm{CE}_{\mathrm{base}}$ + $\mathrm{CE}_{\mathrm{sel}}$
- New build-plan procedure without cost function: $\mathrm{BP}_{\mathrm{smart}}$
- Two cost functions of different precision for two hash join implementations: $\mathrm{CF}_{\mathrm{tru}}$ + $\mathrm{CF}_{\mathrm{est}}$

Preliminaries: Overview



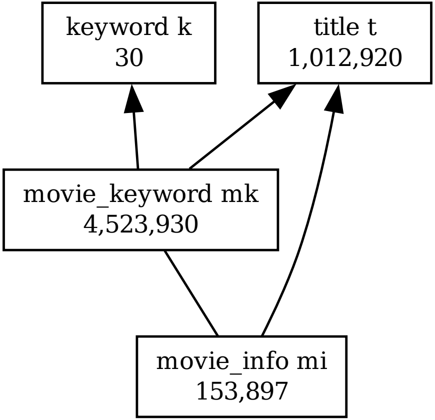
Query Optimizer Architecture

Queries and Query Graphs

SQL Query (JOB Query 3a)

```
SELECT MIN(t.title) AS movie_title
FROM keyword AS k,
     movie_info AS mi,
     movie_keyword AS mk,
     title AS t
WHERE /* some selection predicates */
      AND t.id = mi.movie_id
      AND t.id = mk.movie_id
      AND mk.movie_id = mi.movie_id
      AND k.id = mk.keyword_id;
```

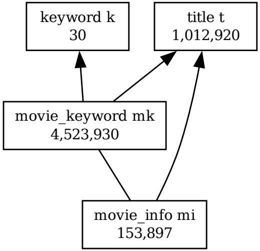
Query Graph



Plan Classes and Cardinality Estimation

Plan class (PC): subset of relations that induces a connected subgraph of the query graph.

- PCs of size 1: $\{\mathtt{k}\}, \{\mathtt{t}\}, \{\mathtt{mk}\}, \{\mathtt{mi}\}$
- PCs of size 2: $\{\mathtt{k}, \mathtt{mk}\}, \{\mathtt{t}, \mathtt{mk}\}, \{\mathtt{t}, \mathtt{mi}\}, \{\mathtt{mk}, \mathtt{mi}\}$
- PCs of size 3: $\{\mathtt{k}, \mathtt{t}, \mathtt{mk}\}, \{\mathtt{k}, \mathtt{mk}, \mathtt{mi}\}, \{\mathtt{t}, \mathtt{mk}, \mathtt{mi}\}$
- PCs of size 4: $\{\mathtt{k}, \mathtt{t}, \mathtt{mk}, \mathtt{mi}\}$

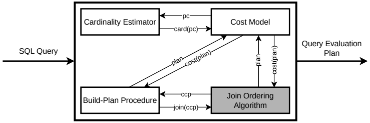


There are many different logical/physical QEPs for the relations of the same plan class.

Observe that all plans of the same plan class have the same result cardinality: $|(\mathtt{k} \bowtie \mathtt{mk}) \bowtie \mathtt{t}| = |(\mathtt{mk} \bowtie \mathtt{t}) \bowtie \mathtt{k}| = \ldots$

$\Rightarrow$ **Cardinality estimation** must provide an estimate for each plan class.

CCPs and Join Ordering Algorithms

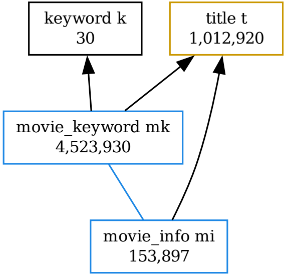


csg-cmp-pair (CCP):
two disjoint plan classes that are connected by at least one edge in the query graph.

Different alternatives to join $\text{pc}(\{\mathtt{t}, \mathtt{mk}, \mathtt{mi}\})$:

- $\text{pc}(\{\mathtt{t}\}) \bowtie \text{pc}(\{\mathtt{mk}, \mathtt{mi}\})$
- $\text{pc}(\{\mathtt{mk}\}) \bowtie \text{pc}(\{\mathtt{t}, \mathtt{mi}\})$
- $\text{pc}(\{\mathtt{mi}\}) \bowtie \text{pc}(\{\mathtt{t}, \mathtt{mk}\})$

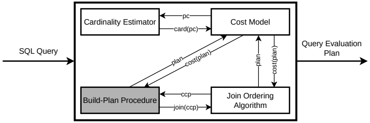
Notation e.g.: $\text{ccp}(\{\mathtt{t}\}, \{\mathtt{mk}, \mathtt{mi}\})$



Join ordering algorithms

- **DPccp**: produces cost-optimal plans, based on dynamic programming.
- **GOO**: greedy heuristics that choose the next join based on the smallest cardinality (**GooCard**) or cost (**GooCost**).

Build-Plan: Traditional Operator Selection

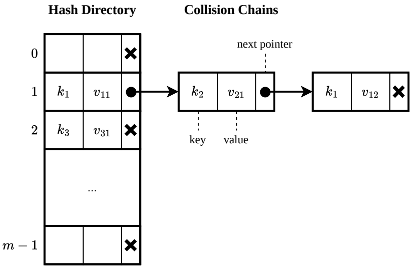


```
function BuildPlanTrad($T_1, T_2$)
    Input: two join trees $T_1, T_2$
    Output: the best join tree for joining $T_1$ and $T_2$
    $BestTree \leftarrow \mathrm{null},\ \mathrm{cost}(BestTree) \leftarrow \infty$
    for each $impl \in Implementations$ do
        $T \leftarrow T_1 \bowtie^{impl} T_2$
        if $\mathrm{cost}(BestTree) > \mathrm{cost}(T)$ then
            $BestTree \leftarrow T$
        $T \leftarrow T_2 \bowtie^{impl} T_1$
        if $\mathrm{cost}(BestTree) > \mathrm{cost}(T)$ then
            $BestTree \leftarrow T$
    return $BestTree$
```

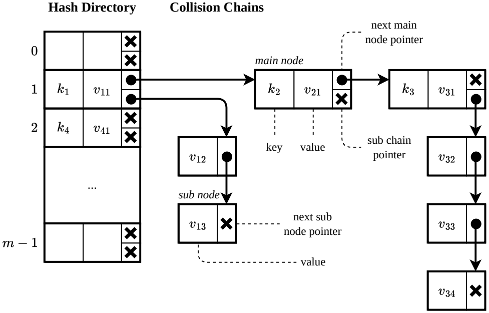
- Exhaustive search.
- Requires cost function evaluation.

Join Implementations and Alternatives

Chaining Hash Join (CH-join)



3D Hash Join (3D-join)

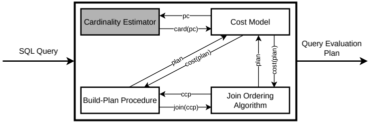


Implementation alternatives

- **Collision chain node design**: unpacked or packed collision chain nodes.
- **Prefetching**: no prefetching, rolling prefetching, AMAC [3]

[3] O. Kocberber, B. Falsafi, and B. Grot. “Asynchronous Memory Access Chaining”. In: *Proc. of the VLDB Endowment (PVLDB)* 9.4 (2015), pp. 252–263

Cardinality Estimation: $\mathrm{CE}_{\mathrm{base}}$ and $\mathrm{CE}_{\mathrm{sel}}$



Single relations (plan classes of size 1):

$$\mathrm{CE}_{\mathrm{X}}(\{R_i\}) := \begin{cases} |R_i| & \text{if X = ‘base’} \\ |\sigma_{p_i}(R_i)| & \text{if X = ‘sel’} \end{cases}$$

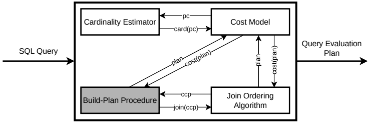
General plan classes ***S***

$$\mathrm{CE}_{\mathrm{X}}(S) := \min_{\mathrm{ccp}(S_1,S_2):\ S=S_1\cup S_2} \mathrm{CE}_{\mathrm{X}}(S,(S_1,S_2))$$

$$\mathrm{CE}_{\mathrm{X}}(S,(S_1,S_2)) := \begin{cases} \min(\mathrm{CE}_{\mathrm{X}}(S_1),\mathrm{CE}_{\mathrm{X}}(S_2)) & \text{if } \quad \mathfrak{U}(S_1) \land \quad \mathfrak{U}(S_2) \\ \mathrm{CE}_{\mathrm{X}}(S_1) & \text{if } \neg\mathfrak{U}(S_1) \land \quad \mathfrak{U}(S_2) \\ \mathrm{CE}_{\mathrm{X}}(S_2) & \text{if } \quad \mathfrak{U}(S_1) \land \neg\mathfrak{U}(S_2) \\ \mathrm{CE}_{\mathrm{X}}(S_1)\cdot\mathrm{CE}_{\mathrm{X}}(S_2) & \text{if } \neg\mathfrak{U}(S_1) \land \neg\mathfrak{U}(S_2) \end{cases}$$

$\mathfrak{U}(S_i)$: $\mathrm{ccp}(S_1, S_2)$ determines S_i uniquely, i.e., the join attributes are a (super-) key of S_i.

Build-Plan: Our Heuristic Approach



- **Goal**: Heuristic approach that does not require cost function evaluation and/or consideration of all possible alternatives.
- Two decisions to be made:
  1. Physical join operator: CH- or 3D-join.
  2. Build side of the hash join.
- **Algorithm**
  - If join attributes on both sides are unique, use the CH-join.
  - If join attributes on both sides are non-unique, use the 3D-join.
  - In both cases, choose the smaller join input as the build side.
  - If the join attributes on one side are unique, but not on the other, we make the following distinction:
    - If card(unique) $\leq 2 \cdot$ card(non-unique), then use CH-join w/ build on unique.
    - Else, use 3D-join w/ build on non-unique.

Evaluation: Overview

Dataset & Queries: Join Order Benchmark (JOB) on the IMDb dataset.

Plan generation components

- Join ordering algorithms: DPccp, GooCard, GooCost
- Build-plan procedures: $\mathrm{BP}_{\mathrm{trad}}$, $\mathbf{BP}_{\mathbf{smart}}$ (using CH- and 3D-join variants)
- Cardinality estimators: $\mathbf{CE}_{\mathbf{base}}$, $\mathbf{CE}_{\mathbf{sel}}$, $\mathrm{CE}_{\mathrm{tru}}$, $\mathrm{CE}_{\mathrm{IA\text{-}M}}$
- Cost functions: $\mathbf{CF}_{\mathbf{tru}}$, $\mathbf{CF}_{\mathbf{est}}$, $\mathrm{CF}_{\mathrm{cout}}$

Plan loss factor

Given a plan class S and a plan P for S. The *loss factor* of P is the true cost of P divided by the true cost of the overall best plan for S.

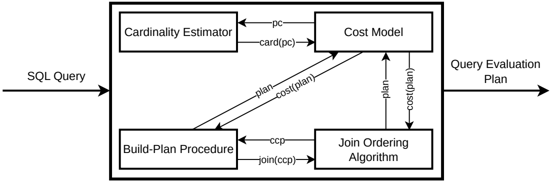
Evaluation: Results

Overall worst case across all JOB queries

- maximum loss factor: 35 785
- average loss factor: 1168

JOA	Build-Plan	Cost Fn.	Card. Est.	Plan Loss (avg)	Plan Loss (max)
DPccp	$\mathrm{BP}_{\mathrm{trad}}$	$\mathrm{CF}_{\mathrm{tru}}$	$\mathrm{CE}_{\mathrm{tru}}$	1.00	1.00
DPccp	$\mathrm{BP}_{\mathrm{smart}}$	$\mathrm{CF}_{\mathrm{cout}}$	$\mathrm{CE}_{\mathrm{base}}$	2.57	6.90
GooCard	$\mathrm{BP}_{\mathrm{smart}}$	—	$\mathrm{CE}_{\mathrm{base}}$	2.27	6.90
GooCard	$\mathrm{BP}_{\mathrm{smart}}$	—	$\mathrm{CE}_{\mathrm{sel}}$	2.32	6.71

Conclusion



In the first version of a DBMS, acceptable plan quality can be achieved using simple QO with the following building blocks:

- Heuristic **join ordering** only based on cardinality estimates: GooCard
- Very simple **cardinality estimation**: CE_{base}
- **Operator selection** using only cardinalities and uniqueness: BP_{smart}

If implemented with proper modularization, simple approaches can be replaced by more sophisticated ones step by step.