LinDP++: Generalizing Linearized DP to Crossproducts and Non-Inner Joins

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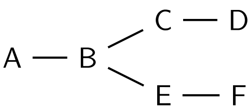
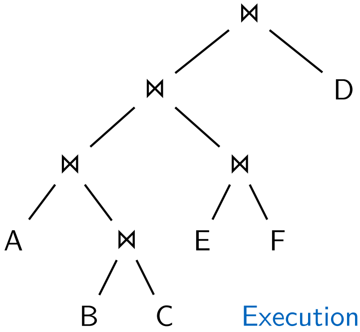
Join Ordering

```
SELECT ...
FROM A, B, C, D, E, F
WHERE A.a=B.a AND B.b=C.b AND B.c=E.c
  AND C.d=D.d AND E.e=F.e
```



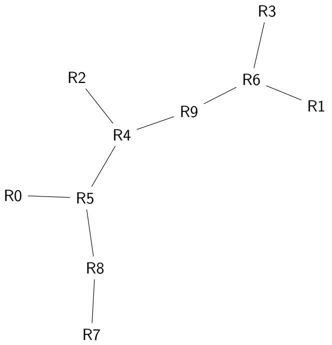
Query Graph



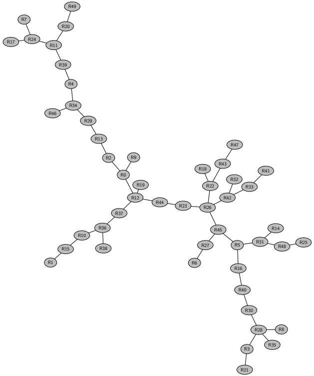
Execution Plan

Problem Complexities

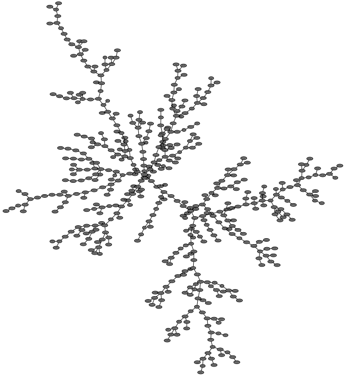
- Join Ordering is NP-Hard



Easy!



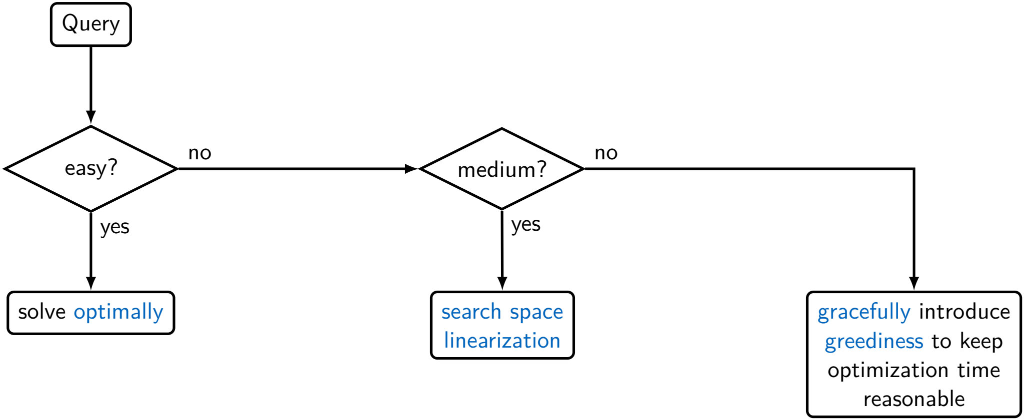
Manageable



Impossible?

- Tableau (DBTEST 2018): Queries regularly involve a few dozen joins
- SAP (BTW 2017): Largest query touches 4,598 relations

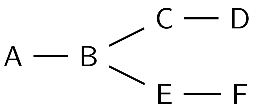
Adaptive Optimization of Very Large Join Queries (SIGMOD 2018)

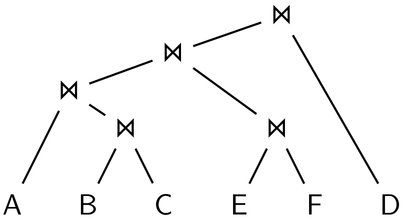


- For performance and correctness reasons: Do not consider crossproducts

Search Space Linearization

- If the order of relations in the optimal plan is known
- Generating the optimal plan from this linearization takes polynomial time
- Optimally combine optimal solutions for subchains





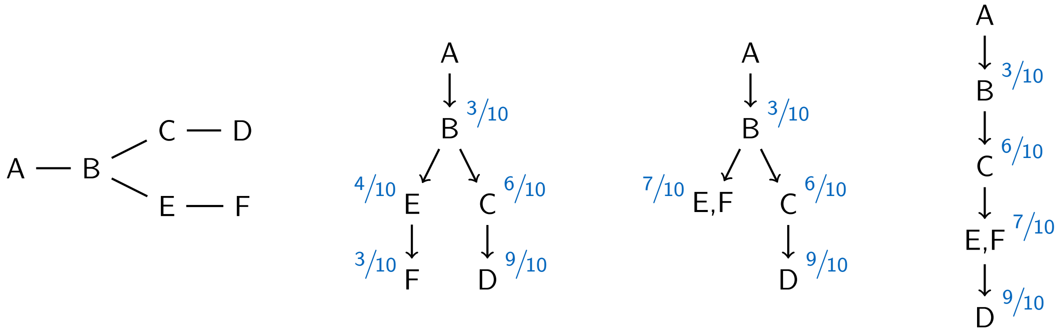
Search Space Linearization

- Of course: Optimal order unknown
- But IKKBZ (TODS 3/1984, VLDB 1986): optimal left-deep plan in $\mathcal{O}(n^2)$
- Using IKKBZ to linearize the search space yields good bushy plans

IKKBZ

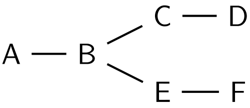
- Requires acyclic query graph (build MST if cyclic)
- Idea: Transform precedence graphs into a linear order
- Assign ranks to nodes (cost/benefit ratio)
- Successively merge child chains increasing in ranks
- Resolve contradictory sequences in child chains by merging them into a single node

IKKBZ

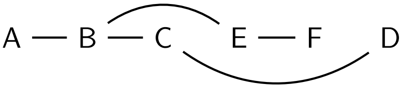


- Build precedence graph (here rooted in A)
- Resolve contradictory sequences in child chains by merging them into a single node
  rank(E) $>$ rank(F), but E has to precede F
- Merge child chains increasing in the nodes rank
  rank(C) $<$ rank(E,F) $<$ rank(D)

Search Space Linearization



Query Graph

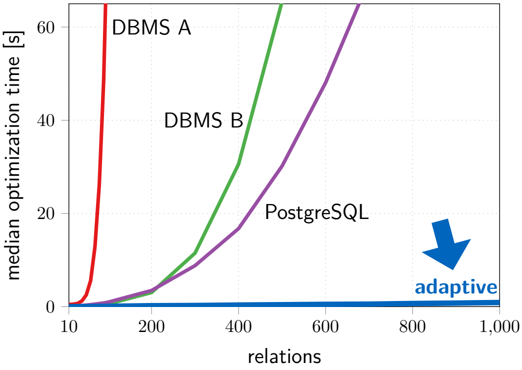


Linearized Search Space

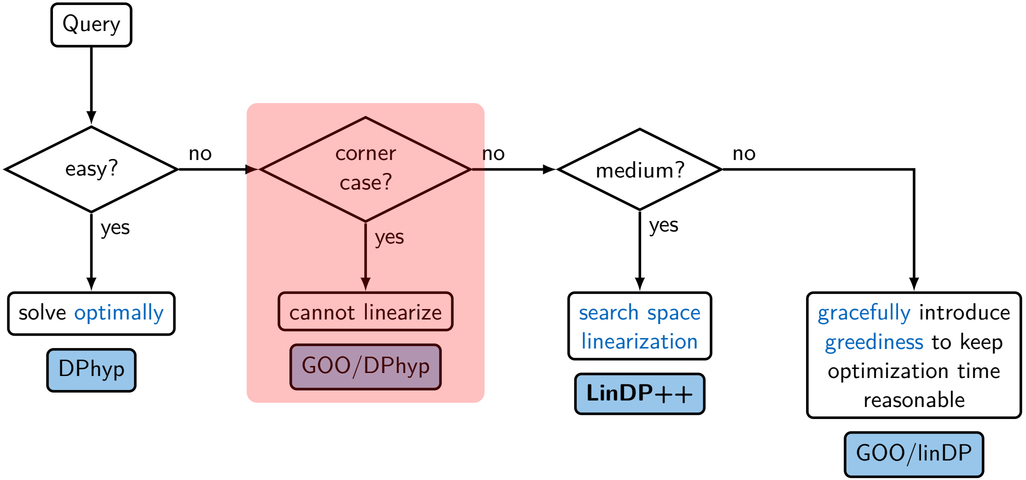
- Repeat this for each relation
- Guarantee: Final plan at least as good as the best left-deep plan

Adaptive Optimization – Achievements (SIGMOD 2018)

- Solve easy cases optimally
- Search Space Linearization: near-optimal plans for common queries
- Gracefully tune down plan quality for the most complex queries
- Optimize queries on hundreds of relations in the blink of an eye



Adaptive Optimization of Very Large Join Queries (SIGMOD 2018)



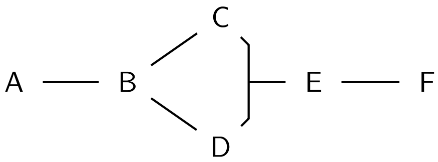
Non-Inner Joins – More Than a Corner Case

- Tableau (DBTEST 2018):
  20% of the queries involve outer joins, up to 247 in a single query
- Others also report significant numbers of queries with outer joins
- Non-Inner joins impose reordering constraints
- Expressed using hyperedges (Moerkotte et al. SIGMOD 2013)

Non-Inner Joins – Search Space Linearization?

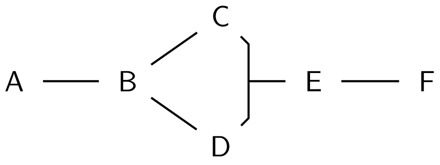
- IKKBZ only handles regular graphs
- Still: Given a proper linearization, polynomial time construction of bushy plan
- **How to extend IKKBZ to generate linearizations for hypergraphs?**

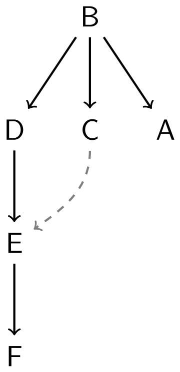
Precedence for Hypergraphs



- Hyperedge {C,D} – {E}
- Backward and forward hyperedges

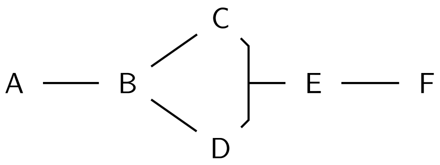
Precedence for Hypergraphs – Backward Hyperedges

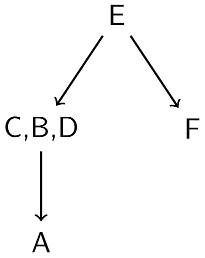




- Precedence DAG, multiple relations have to precede
- During merge: Ensure all precedence constraints are satisfied

Precedence for Hypergraphs – Forward Hyperedges





- Join towards multiple relations, no left deep solution
- Recursively linearize group {C,D}: C,B,D
- Guarantee: Final plan at least as good as the best left-deep plan if there exists one

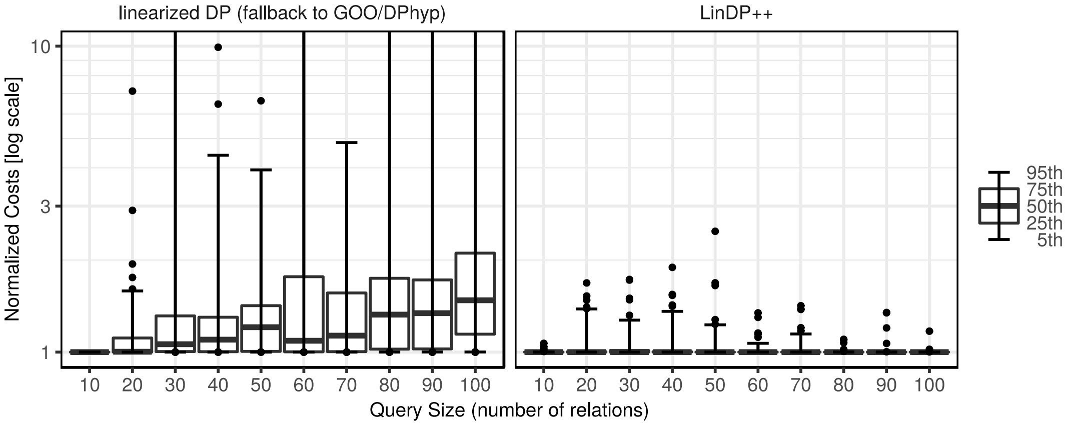
Experiments

- More than 10 different join ordering algorithms
- 60 seconds timeout per query
- Standard benchmarks (TPC-H, TPC-DS, etc.) easily optimized by full DP

⇒ 1,000 realistic random tree queries
  - Up to 100 relations each
  - Random reordering constraints

Plan Quality

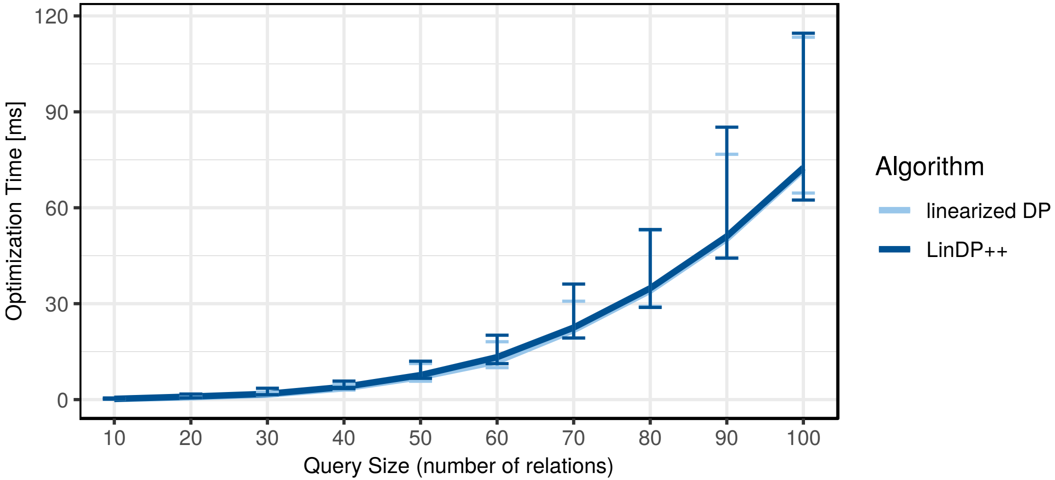
- Cost normalized to the best known plan per query



- LinDP++ generates clearly superior plans

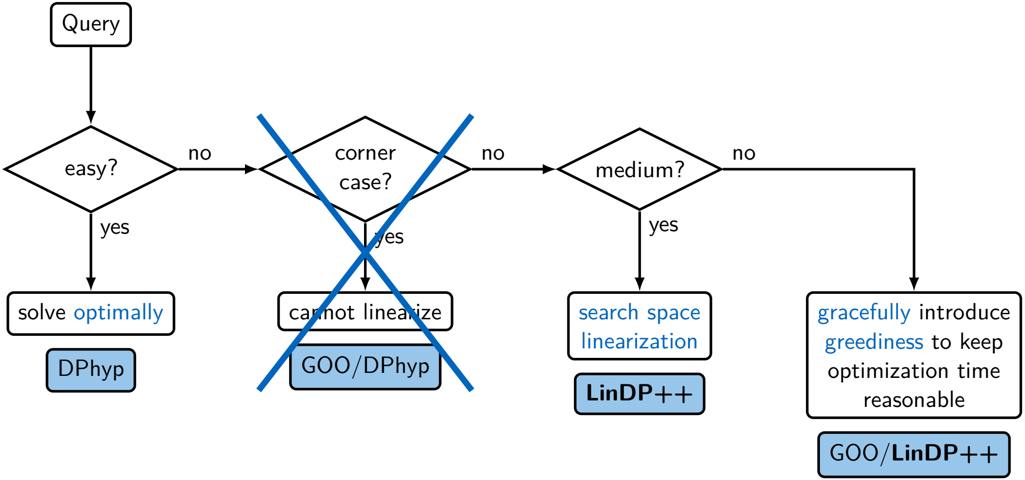
Optimization Time

- Pure inner join queries vs. queries with outer joins



- LinDP++ handles non-inner joins as fast as inner joins

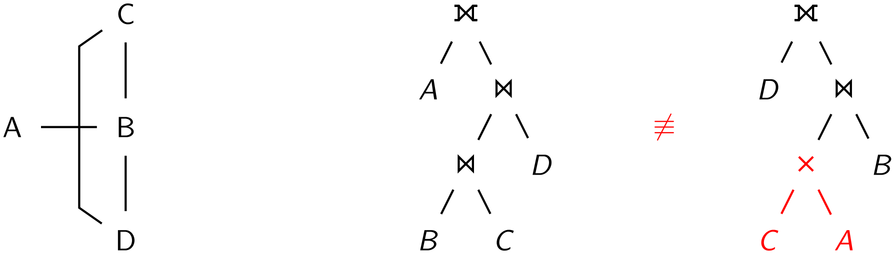
Adaptive Optimization of Very Large Join Queries (SIGMOD 2018)



- For performance and correctness reasons: Do not consider crossproducts

Do Not Consider Crossproducts

1. Performance
   - Exponential search space regardless of the query's structure
   - Most considered crossproducts will not reduce cost ($A \times B \in \mathcal{O}(|A||B|)$)
2. Correctness
   - Crossproducts in the presence of non-inner joins can yield wrong query results



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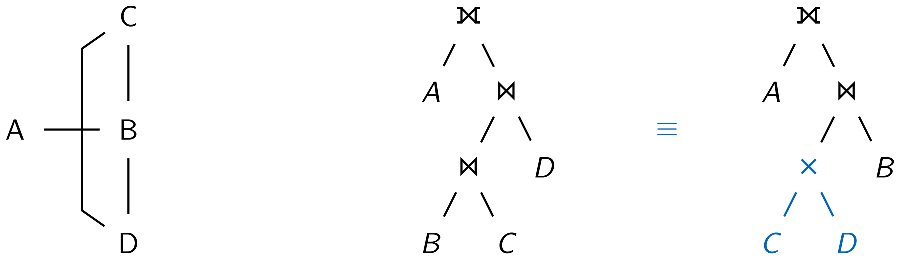


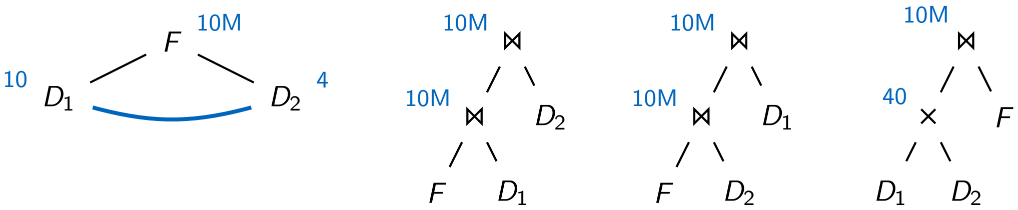
Do Consider Some Crossproducts

- Observation: Some plans would significantly benefit from crossproducts
- TPC-DS: Crossproducts improve geometric mean of cost by 15%
- However: 82% of the queries do not benefit at all from crossproducts
- Thus: Do consider some crossproducts (ideally the important ones)

- **How to efficiently discover the valid and important crossproducts?**

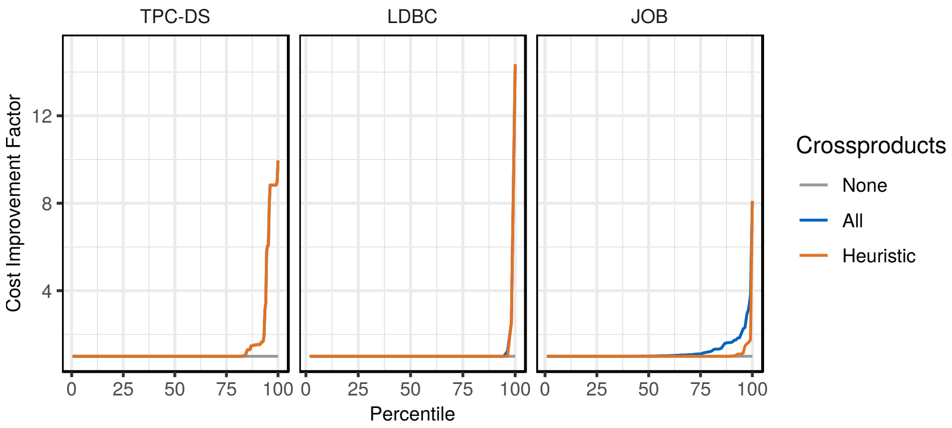
Crossproducts

- Intuitively: Crossproduct to avoid massive intermediate results
- That is: Bypass expensive joins
- Idea: Check neighboring inner joins for opportunities



- If crossproduct is smaller than both intermediate results:
  Add explicit edge to the query graph

Cost Improvement



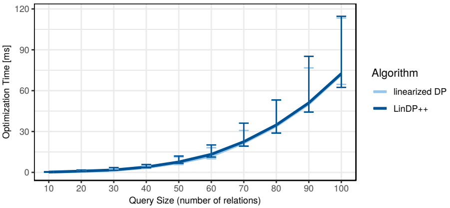
Optimization Overhead

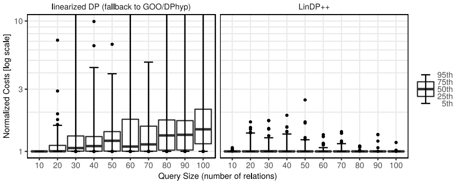
Algorithm	TPC-H	TPC-DS	LDBC	JOB	SQLite
LinDP++	8%	6%	0	8%	0
DPhyp	12%	2.8X	0	76%	0
All Crossproducts	2.4X	214X	53X	83X	152X

- LinDP++ efficiently considers most of the relevant crossproducts

LinDP++

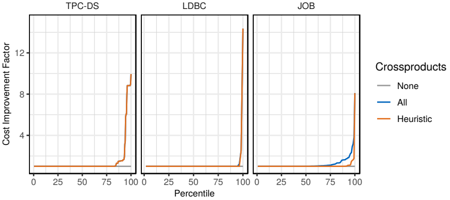
Optimize as fast as pure inner join queries





Generate significantly better plans

Efficiently consider promising crossproducts



Bonus Slides

Standard Benchmarks

- Plan Quality (normalized cost)

Algorithm	TPC-H	TPC-DS	LDBC	JOB	SQLite
DPhyp	1.00	1.00	1.00	1.00	1.00
LinDP++	1.00	1.00	1.00	1.07	1.00

- Optimization Time (ms)

Algorithm	TPC-H	TPC-DS	LDBC	JOB	SQLite
DPhyp	0.4	90	1.2	227	2.2K
linearized DP	1.4	18.7	4.4	33.4	4.7K
LinDP++	1.6	19.9	4.4	36.2	4.7K

- Standard benchmarks barely a challange for an optimizer