Relational Databases can Handle Graphs Too!

Altan Birler

Technische Universität München

UMBRA LDBC

- UMBRA: Very fast *Relational* DBMS
- LDBC-BI: OLAP *Graph* Workload. 2 Graph, 1 Relational System
- Graph queries → SQL

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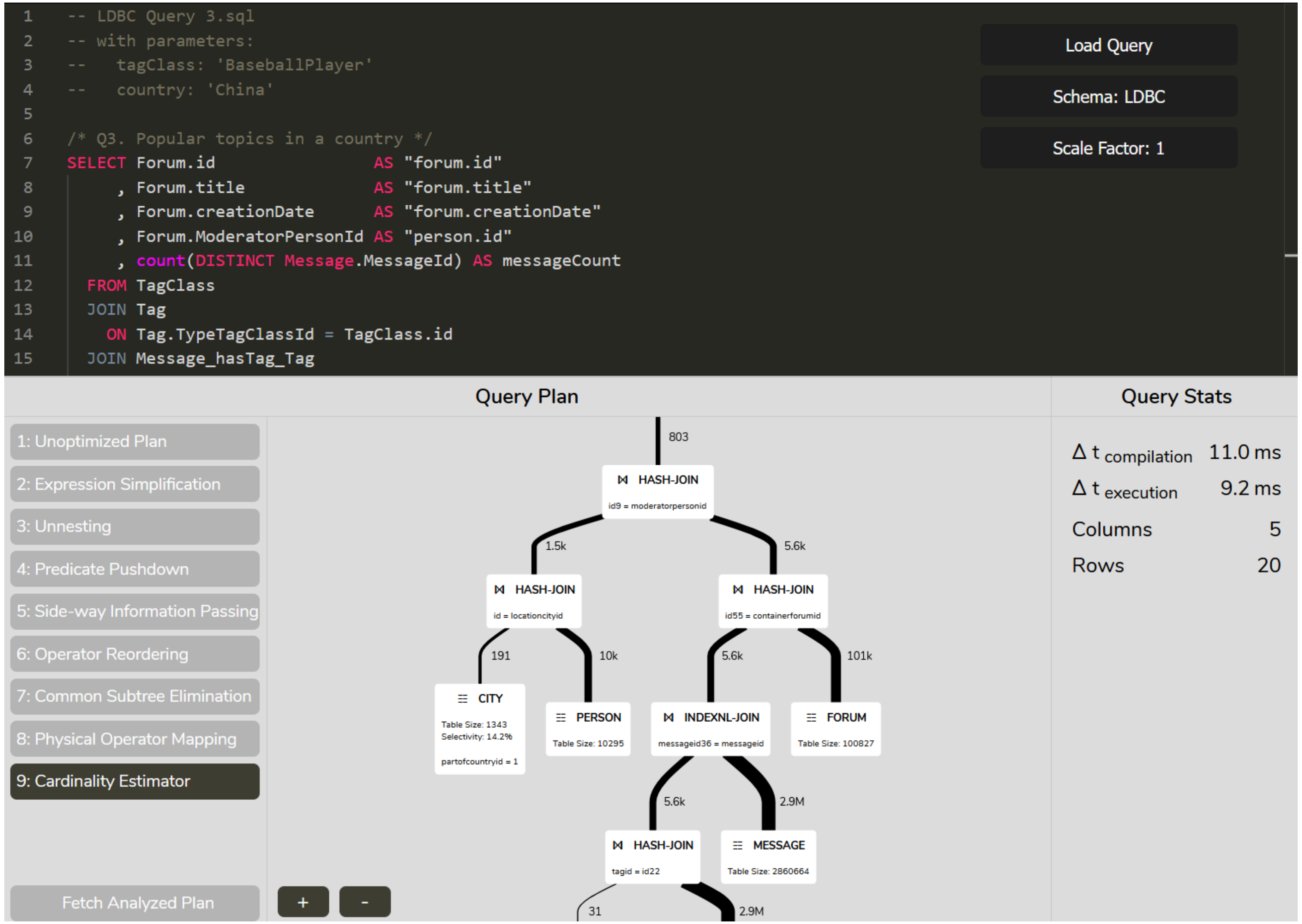
- LDBC-BI: OLAP *Graph* Workload. 2 Graph, 1 Relational System
- Graph queries → SQL
- Umbra is fast at executing *every single query*
  - *Including the shortest path queries!*

umbra-db.com/interface



```sql
-- LDBC Query 3.sql
-- with parameters:
--   tagClass: 'BaseballPlayer'
--   country: 'China'

/* Q3. Popular topics in a country */
SELECT Forum.id                AS "forum.id"
     , Forum.title             AS "forum.title"
     , Forum.creationDate      AS "forum.creationDate"
     , Forum.ModeratorPersonId AS "person.id"
     , count(DISTINCT Message.MessageId) AS messageCount
  FROM TagClass
  JOIN Tag
    ON Tag.TypeTagClassId = TagClass.id
  JOIN Message_hasTag_Tag
```

Query Stats

Δ t compilation 11.0 ms

Δ t execution 9.2 ms

Columns 5

Rows 20

- A relational DB is great at executing *every single graph query*
  - *What is going on here?*

Attribution: Twitter, https://github.com/twitter/twemoji/

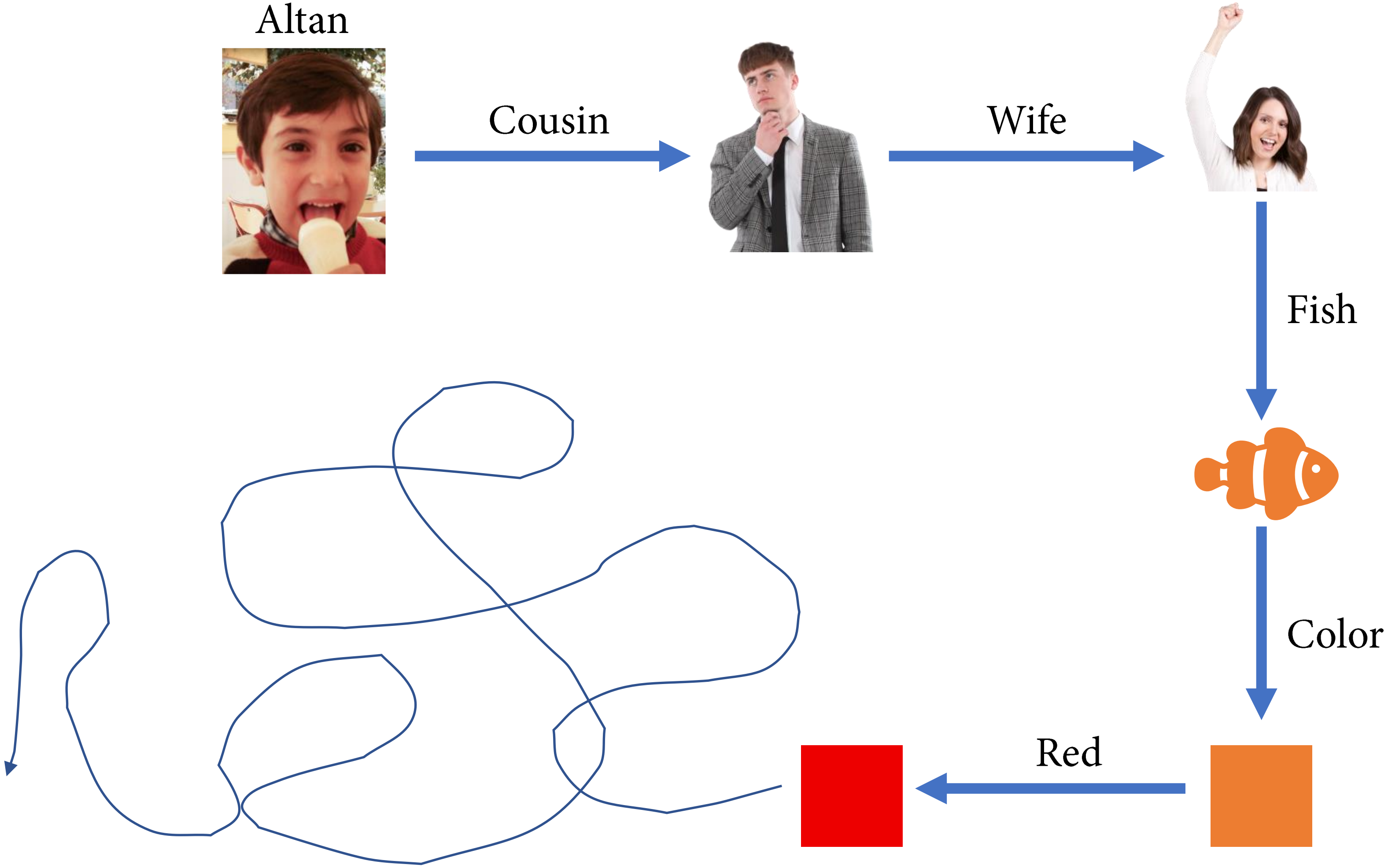
~~`// Umbra.cpp: L192`~~

~~`if (query == ldbc19)`~~
~~`    executeFastCppImplementation();`~~

The Graph Perspective

- “Navigate deep hierarchies” *neo4j.com/developer/graph-database/*
- **Connections**

The Graph Perspective



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Cousin

Wife

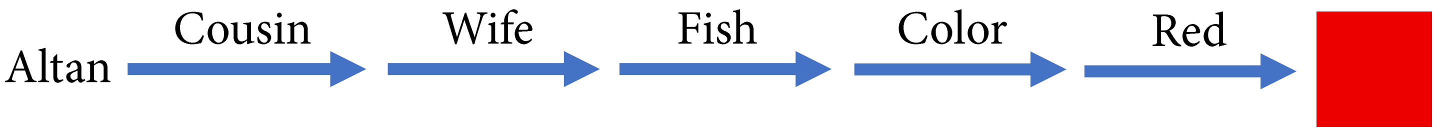
Fish

Color

Red

The Graph Perspective

Scalable?



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Scalable? *Now you are thinking with relations.*

5000000		*2000000*
People	*join*	**CousinsOfPeople**

The Relational Perspective

- A *scalable* model of the world: “*SQL is embarrassingly parallel*”
- **Big** (multi-)sets of unordered data
- Highly scalable, deeply researched, simple, standard operators
    - *Join, Group By*
- ***Breadth*** *is scalable*
    - *Depth is not*

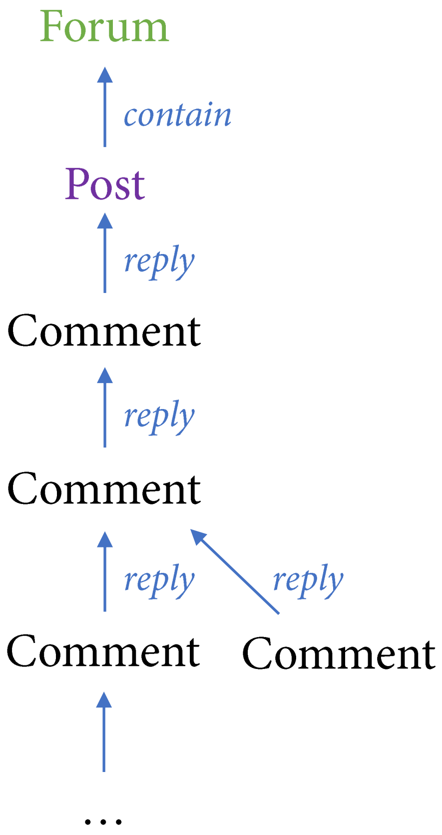
Is My Query Scalable?

- Can you express it with set oriented relational algebra?
  - Yes: *Most likely scalable*
  - No: *You might have some trouble*

How To Scale LDBC BI Queries

- Express them in relational algebra (SQL)
- Eliminate depth, increase breadth

Eliminate depth



Forum

contain

Post

reply

Comment

reply

Comment

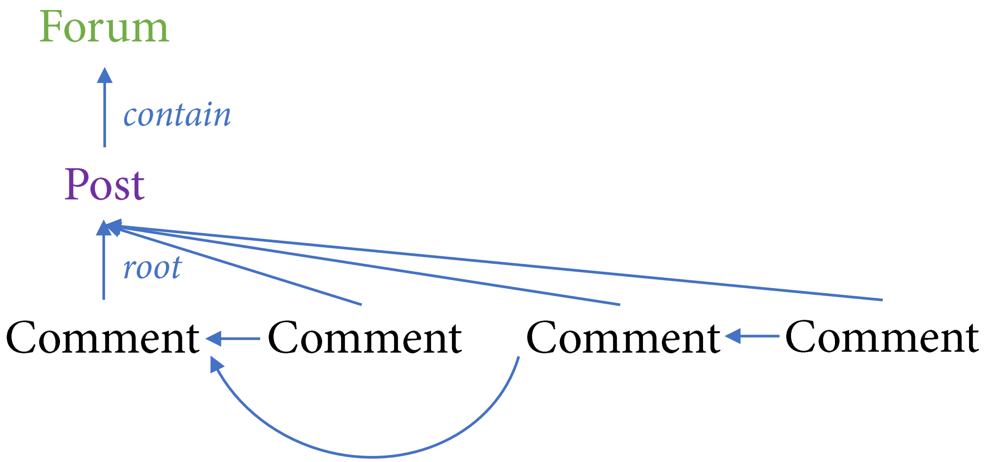
reply

reply

Comment

Comment

…



Forum

contain

Post

root

Comment

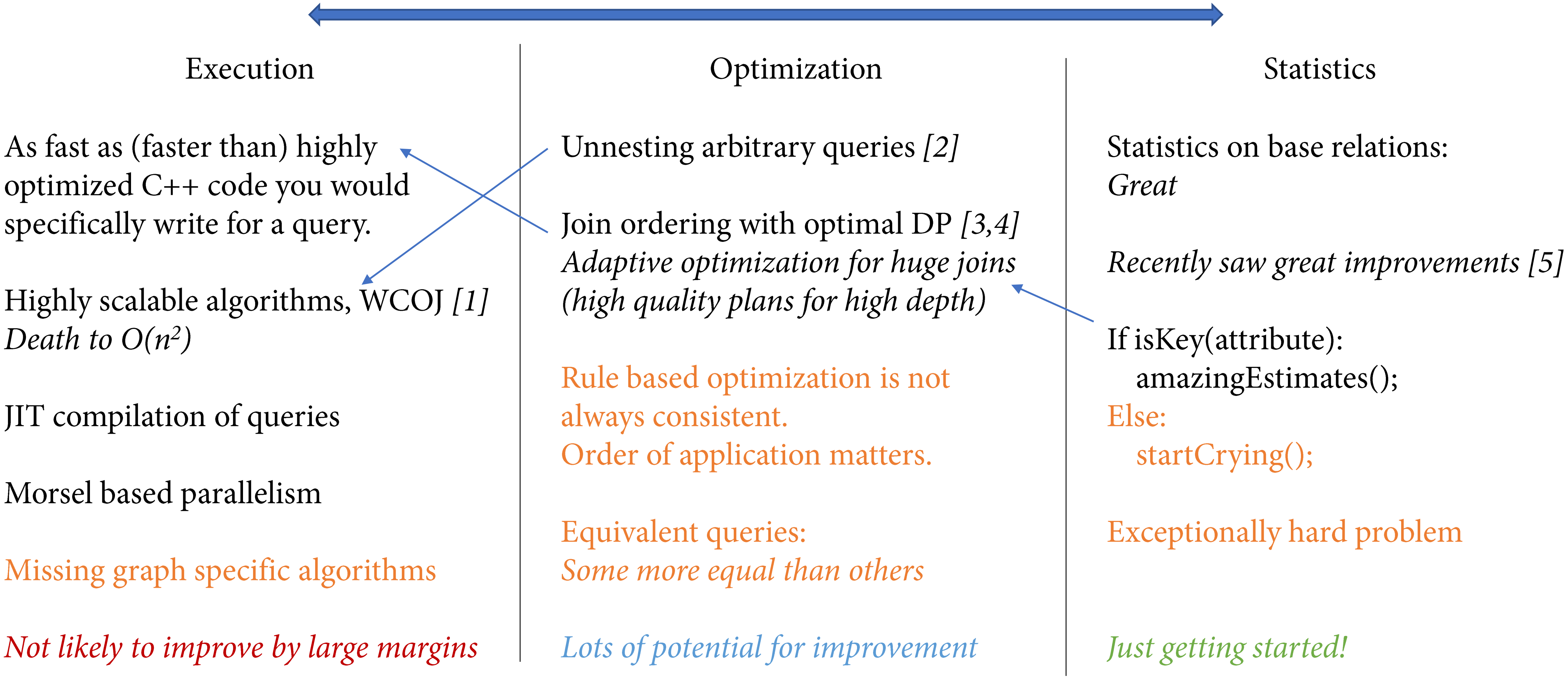
Comment

Comment

Comment

- Works since there are no link/cut operations
- *Unforeseen (positive) consequences*
  - Removing recursions improves cardinality estimates which improve accuracy of the optimizer
- Query: *Average number of messages per forum*
  - 800ms vs 80ms

How to Beat Umbra



Execution

As fast as (faster than) highly optimized C++ code you would specifically write for a query.

Highly scalable algorithms, WCOJ *[1]*
Death to $O(n^2)$

JIT compilation of queries

Morsel based parallelism

Missing graph specific algorithms

Not likely to improve by large margins

Optimization

Unnesting arbitrary queries *[2]*

Join ordering with optimal DP *[3,4]*
Adaptive optimization for huge joins (high quality plans for high depth)

Rule based optimization is not always consistent.
Order of application matters.

Equivalent queries:
Some more equal than others

Lots of potential for improvement

Statistics

Statistics on base relations:
Great

Recently saw great improvements [5]

```
If isKey(attribute):
   amazingEstimates();
Else:
   startCrying();
```

Exceptionally hard problem

Just getting started!

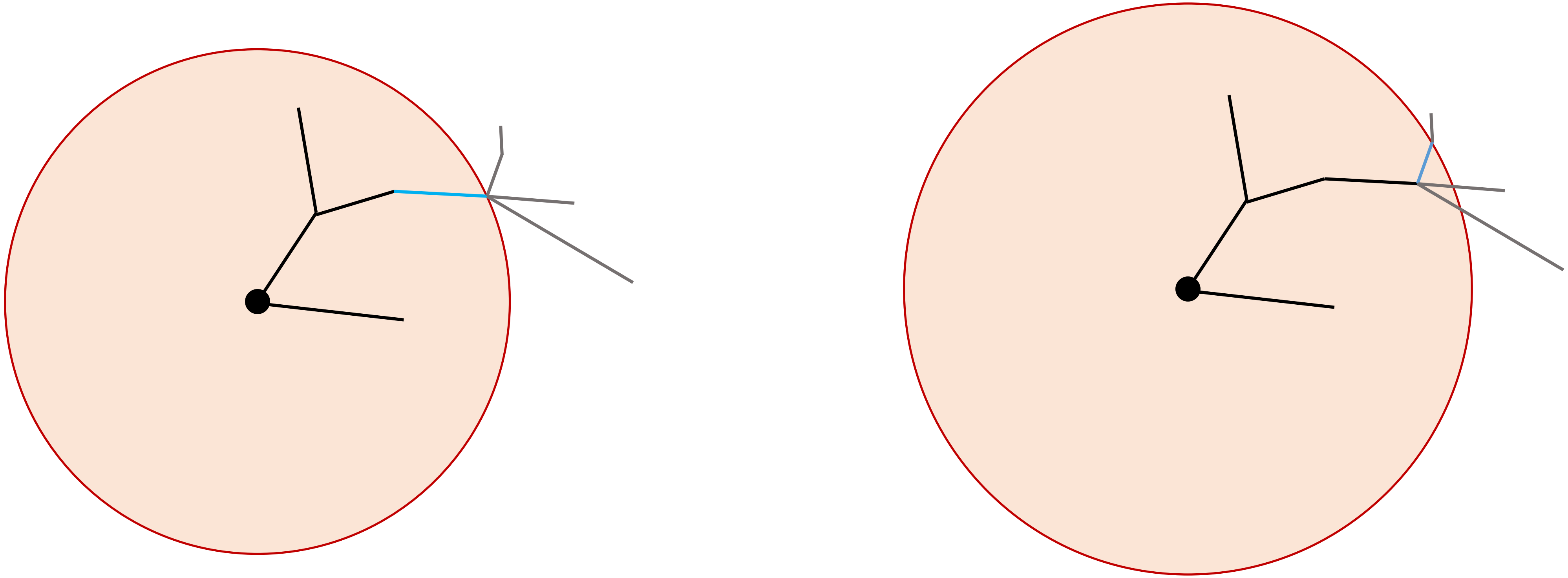
LDBC BI SQL Queries

- The queries changed over time
  - Over 10x improvement gained by rewriting queries
  - *The optimizer should have been doing what we had to do by hand!*
    - Remove redundant joins with redundant relations
    - Common subquery elimination
- Are you interested in execution?
  - Check out the latest query versions
- Are you interested in optimization?
  - Go through the git history and check out earlier query versions

SQL Shortest Path (PostgreSQL dialect)

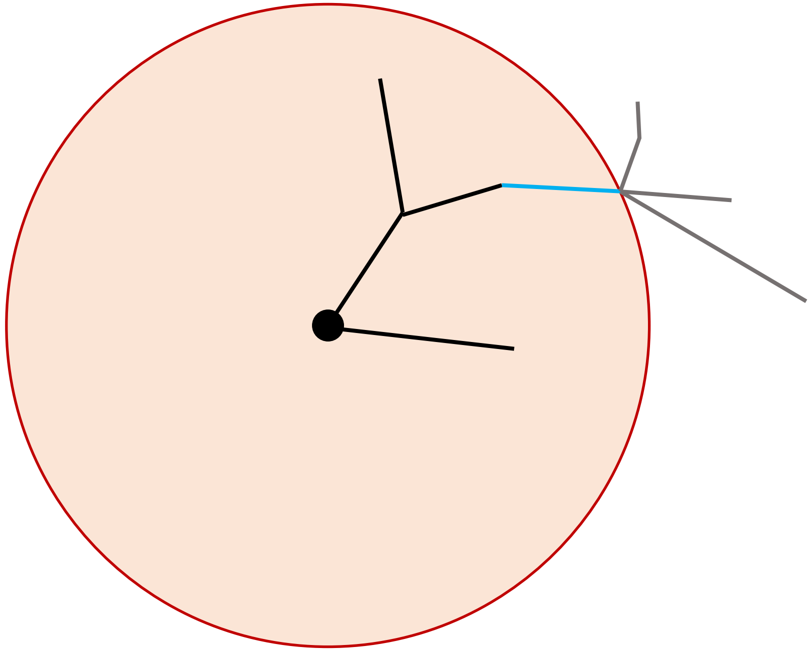
```sql
shorts(dir, gsrc, dst, w, dead, iter) as (
    (
        select false, f, f, 0::double precision, false, 0 from srcs
        union all
        select true, t, t, 0::double precision, false, 0 from dsts
    )
    union all
    (
        with
        ss as (select * from shorts),
        toExplore as (select * from ss where dead = false order by w limit 1000),
        -- assumes graph is undirected
        newPoints(dir, gsrc, dst, w, dead) as (
            select e.dir, e.gsrc as gsrc, p.dst as dst, e.w + p.w as w, false as dead
            from path p join toExplore e on (e.dst = p.src)
            union all
            select dir, gsrc, dst, w, dead or exists (select * from toExplore e where e.dir = o.dir and e.gsrc = o.gsrc and e.dst = o.dst) from ss o
        ),
        fullTable as (
            select distinct on(dir, gsrc, dst) dir, gsrc, dst, w, dead
            from newPoints
            order by dir, gsrc, dst, w, dead desc
        ),
        found as (
            select min(l.w + r.w) as w
            from fullTable l, fullTable r
            where l.dir = false and r.dir = true and l.dst = r.dst
        )
        select dir,
               gsrc,
               dst,
               w,
               dead or (coalesce(t.w > (select f.w/2 from found f), false)),
               e.iter + 1 as iter
        from fullTable t, (select iter from toExplore limit 1) e
    )
),
```

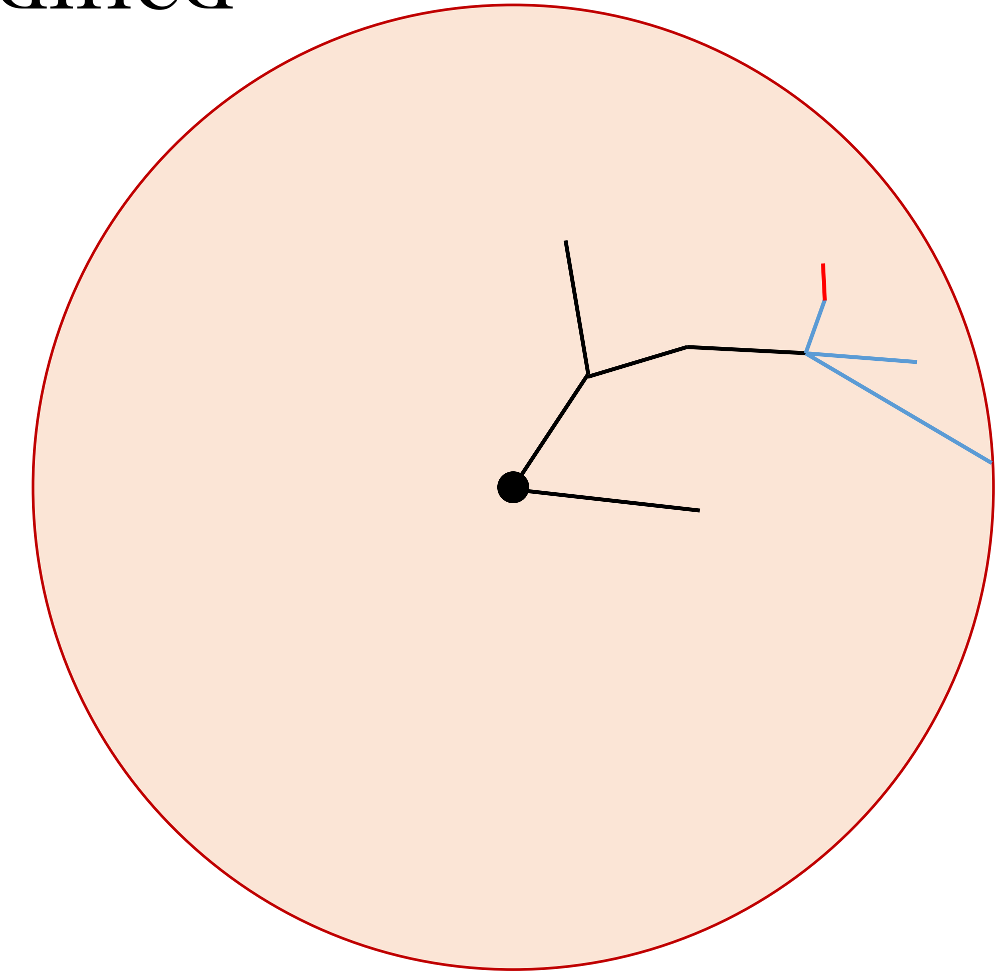
Dijkstra's Algorithm



*Visit nodes **one by one** by increasing distance*
Invariant: Every path within the circle has been seen

Dijkstra’s Algorithm Modified





*Visit nodes **1000s at a time** by increasing distance*

~~**Invariant:** Every path within the circle has been seen~~

We have to make sure no shorter path is available

Additional improvement: Bidirectional search

Hacking SQL Recursion

- Can’t access results of arbitrary recursion steps
  - So just propagate everything you ever compute at every step!
  - *Absolutely horrible, destroys memory and efficiency*
    - But we still beat the other graph systems!
    - This emphasizes the importance of breadth of depth

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        from fullTable t, (select iter from toExplore limit 1) e
    )
),
```

References

[1] Michael J. Freitag et al. “Adopting Worst-Case Optimal Joins in Relational Database Systems”. In: Proc. VLDB Endow. 13.11 (2020), pp. 1891–1904.

[2] Thomas Neumann and Alfons Kemper. “Unnesting Arbitrary Queries”. In: BTW. Vol. P-241. LNI. GI, 2015, pp. 383–402.

[3] Thomas Neumann and Bernhard Radke. “Adaptive Optimization of Very Large Join Queries”. In: SIGMOD Conference. ACM, 2018, pp. 677–692.

[4] Bernhard Radke and Thomas Neumann. “LinDP++: Generalizing Linearized DP to Crossproducts and Non-Inner Joins”. In: BTW. Vol. P-289. LNI. Gesellschaft für Informatik, Bonn, 2019, pp. 57–76.

[5] Philipp Fent and Thomas Neumann. “A Practical Approach to Groupjoin and Nested Aggregates”. In: Proc. VLDB Endow. 14.11 (2021), pp. 2383–2396.