WRITING RECURSIVE QUERIES

RETRIEVING HIERARCHY DATA FROM RELATIONAL TABLES

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POSTGRESCONF US 2019

IS THIS TALK RIGHT FOR YOU?

What we will cover

- Why we need recursive queries
- How they work
- How to write them

What you should know

- Basic knowledge of SQL through outer joins
- General programming concepts
- Slides and SQL:

  https://github.com/benjlis/talk-writing-recursive-queries

ABOUT ME

- Data Engineer at LEI Smart
- Writes recursive queries on corporate hierarchy data
- Initially found recursive SQL a bit confusing
- Using PostgreSQL since 2015
- Started working with Oracle databases in 1988!
- Adjunct Associate Faculty in Applied Analytics at Columbia University
- Held various technical, product, and management roles on Wall Street
- LinkedIn and Twitter

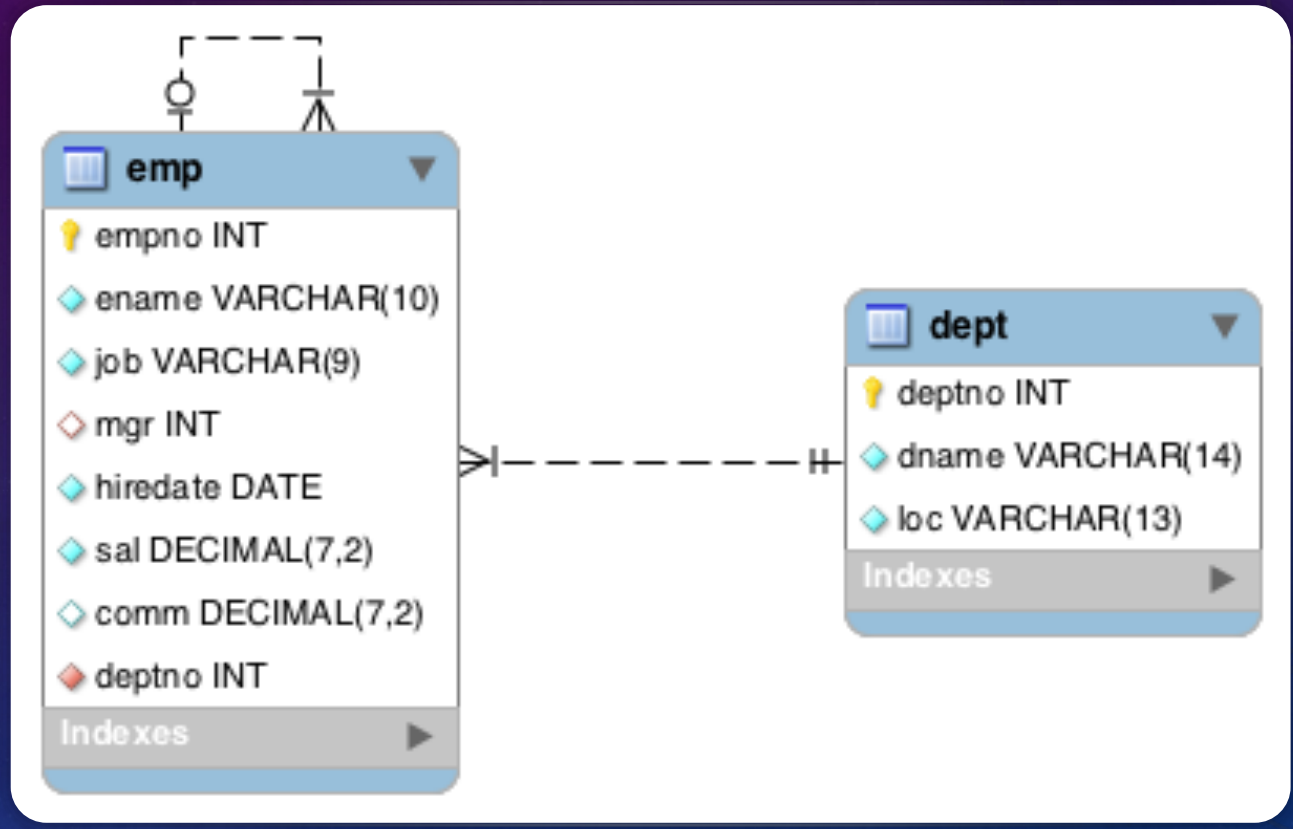
AGENDA

- Motivation
- Understanding Recursive SQL
- Writing Recursive Queries
- Next Steps
- Questions & Discussion

MOTIVATION

WHY WE NEED RECURSIVE SQL

HR DATABASE



hrex-create.sql

LET'S QUERY EMPLOYEES, THEIR BOSS & THE BOSS'S BOSS

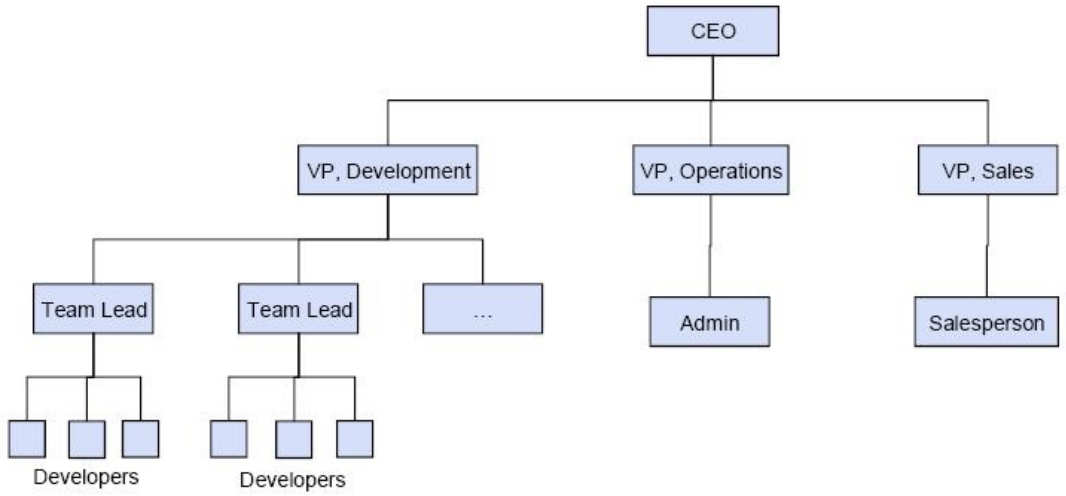
```sql
-- employees and their boss
select e.ename, e.job, b.ename boss
    from emp e left join emp b on (e.mgr = b.empno);

-- employees, their boss and boss's boss
select e.ename, e.job, b.ename boss, bb.ename bossboss
    from emp e left join emp b on (e.mgr = b.empno)
               left join emp bb on (b.mgr = bb.empno);
```

boss-queries.sql

LET'S QUERY EMPLOYEES' ENTIRE REPORTING LINE

HMMM… HOW DO WE DO THAT?

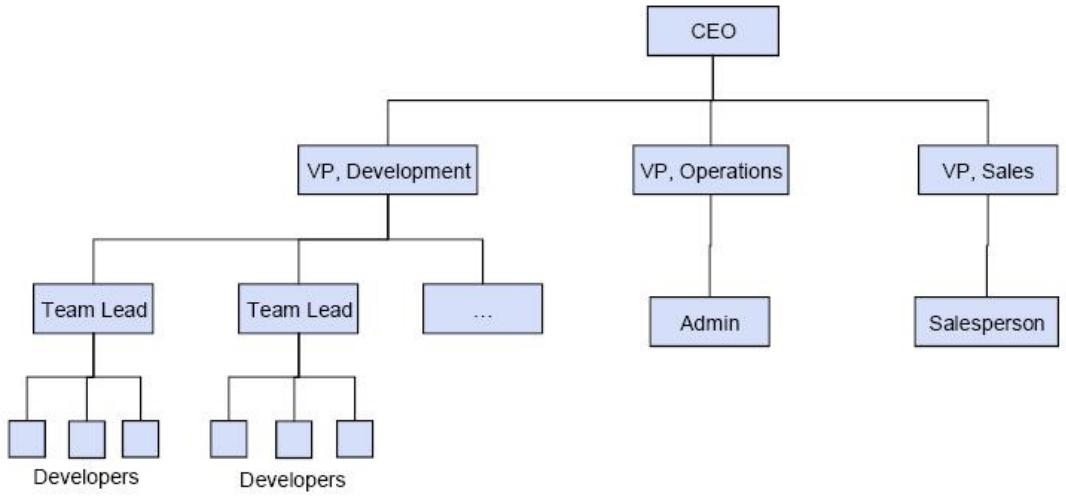


IDEA 1: EXTEND CURRENT APPROACH

"Add a few more JOINs"

Need to know the number of hierarchy levels in advance

Not realistic or robust!



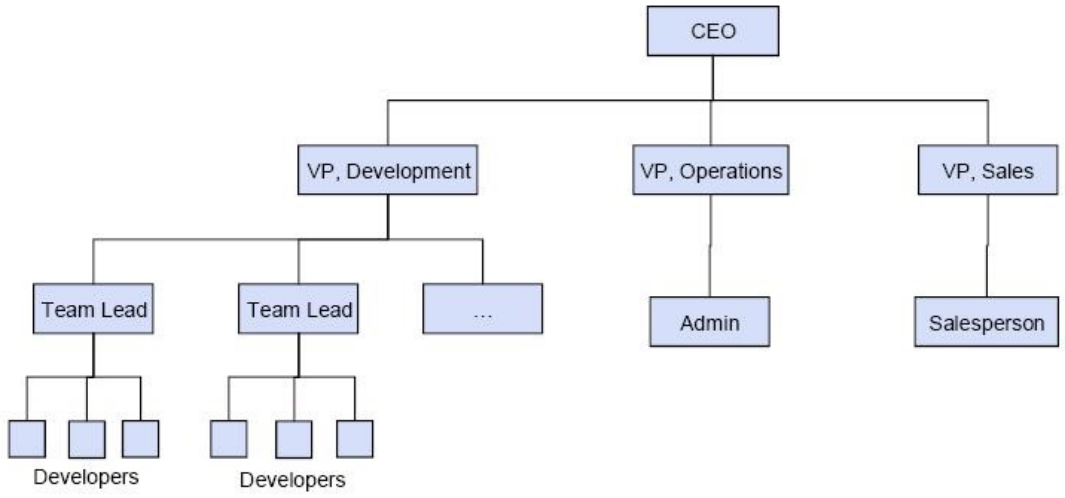
IDEA 2: WRITE A PROGRAM

Use Python, Java, PL/pgSQL, etc.

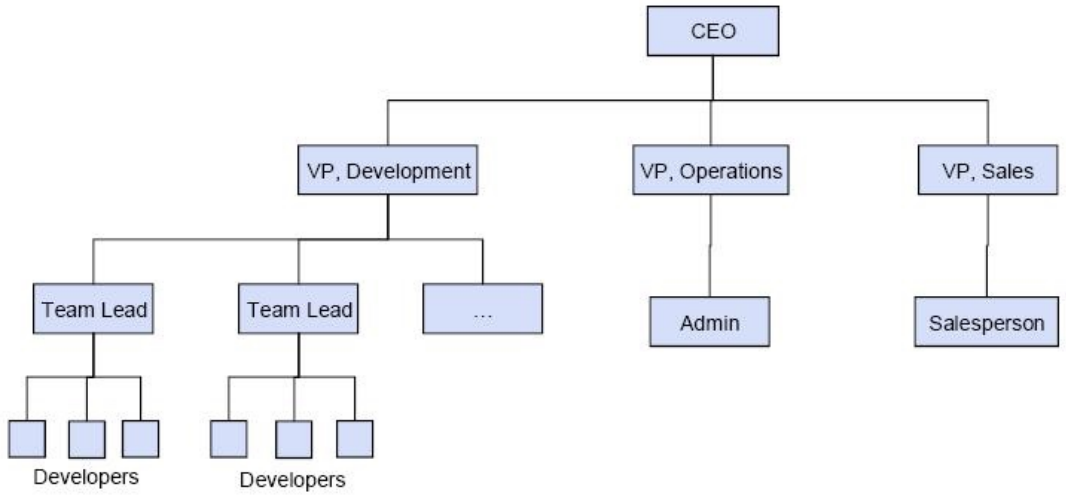
Query all employees

- For each employee get their boss's record and then their boss's boss's record, etc. until you get a NULL

Complex and resource consumptive!



SHOULDN'T WE BE ABLE TO WRITE THIS QUERY IN SQL?



WE SHOULD BE ABLE TO WRITE THIS QUERY IN SQL

- In the early days (decades) of SQL & relational databases we couldn’t
- Writing a program (Idea 2) was the only solution
- Other names for the hierarchy problem:
  - Transitive Closure
  - Bill of Materials
  - Parts Explosion
- Good news: We can write this query in modern SQL using recursive SQL!

UNDERSTANDING RECURSIVE SQL

KEY IDEAS, CTE, SYNTAX, STRUCTURE & EVALUATION

RECURSIVE SQL SUPPORT

Part of ISO Standard SQL

Introduced in SQL:1999 (aka SQL 3)

Supported in

PostgreSQL

Oracle

SQL Server

DB2

KEY IDEAS

- **re·cur·sive /rəˈkərsiv/**: a program or routine of which a part requires the application of the whole, so that its explicit interpretation requires in general many successive executions
- Self-referencing
  - Your Bosses = Your Manager + Your Manager's Bosses
- Recursive SQL is an iterative process
  - Think while loops
  - But SQL is declarative!!!!
- Tip: Put aside knowledge of recursion in programming
- Recursive SQL uses Common Table Expressions (CTEs)

COMMON TABLE EXPRESSION (CTE) EXAMPLE

```
with deptcomp(deptno, dname, empcnt, avgsal, totsal, totcomm, totcomp) as
    (select deptno, dname, count(emp), round(avg(sal), 2), sum(sal),
            coalesce(sum(comm), 0), sum(sal + coalesce(comm, 0))
        from dept natural join emp
        group by deptno, dname)
select * from deptcomp where empcnt >= 5 and totcomm = 0;
```

cte.sql

- Primarily used to simplify queries
- Think of as inline view(s)

RECURSIVE CTE STRUCTURE

- Keyword: recursive
- Always a UNION or UNION ALL of
  - Non-recursive select
  - Recursive select

```
with recursive <cte-name>(<col-names>) as (
    <non-recursive select>
        union [all]
    <recursive select>
)
select ... from <cte-name> ...;
```

NON-RECURSIVE SELECT

- Evaluated 1st - where we start
- FROM clause:
  - Must not refer to <cte-name>
  - Refers to table containing hierarchy

```
with recursive <cte-name>(<col-names>) as (
    <non-recursive select>
        union [all]
    <recursive select>
)
select ... from <cte-name> ...;
```

RECURSIVE SELECT

- Evaluated 2..N times
- FROM clause:
  - Must reference <cte-name>
  - Join of the <cte-name> and table containing hierarchy
- N is a function of the data and the recursive select's where clause

```
with recursive <cte-name>(<col-names>) as (
    <non-recursive select>
        union [all]
    <recursive select>
)
select ... from <cte-name> ...;
```

RECURSIVE CTE EVALUATION

QR = Query Results; WT = Working Table

Both initially empty

1. Execute <non-recursive select>
2. Add results to QR and WT
3. Repeat until WT is empty
    a. Execute <recursive select> using WT data for <cte-name>
    b. Add results to QR
    c. Replace WT with results

```
with recursive <cte-name>(<col-names>) as (
    <non-recursive select>
        union [all]
    <recursive select>
)
select ... from <cte-name> ...;
```

WRITING RECURSIVE QUERIES

LET'S GET DOWN TO IT!

WHAT IS ADAMS REPORTING LINE?

```
with recursive rl(empno, ename, job, mgr) as
(select empno, ename, job, mgr from emp where ename = 'ADAMS'
    union all
 select b.empno, b.ename, b.job, b.mgr from rl r join emp b on r.mgr = b.empno)
select * from rl;
```

rl.sql

ALL EMPLOYEES FROM CEO TO ENTRY LEVEL

```
with recursive oc(empno, ename, job, mgr) as
(select empno, ename, job, mgr from emp where mgr is null
    union all
 select s.empno, s.ename, s.job, s.mgr from oc join emp s on oc.empno = s.mgr)
select * from oc;
```

oc.sql

INCLUDE A LEVEL

```
with recursive oc(level, empno, ename, job, mgr) as
(select 1, empno, ename, job, mgr
    from emp where mgr is null
     union all
 select level+1, s.empno, s.ename, s.job, s.mgr
    from oc join emp s on oc.empno = s.mgr)
select * from oc;
```

oc-level.sql

INCLUDE A PATH

```
with recursive oc(level, empno, ename, job, mgr, rl) as
(select 1, empno, ename, job, mgr, array[ename]::text
    from emp where mgr is null
     union all
 select level+1, s.empno, s.ename, s.job, s.mgr, oc.rl || array[s.ename]::text
    from oc join emp s on oc.empno = s.mgr)
select * from oc order by rl;
```

oc-path.sql

NEXT STEPS

RECOMMENDED READINGS & BEYOND HIERARCHY

RECOMMENDED READINGS

- PostgreSQL documentation
- Fun with SQL: Recursive CTEs in Postgres – Craig Kerstiens
- Modern SQL in Open Source and Commercial Databases (slides 45-60) – Markus Winand
- Exporting a Hierarchy in JSON: with recursive queries - Dmitri Fontaine
- Joe Celko's Trees and Hierarchies in SQL for Smarties (Book)

BEYOND HIERARCHY

- Hierarchy queries are the most common application of recursive SQL, but not the only application!
- Pretty wild recursive SQL queries:
  - Solving the Traveling Salesman Problem with Postgres Recursive CTEs - Periscope Data
  - Mandelbrot Set
  - tic-tac-toe
- My views:
  - Can doesn't mean should
  - Worth studying for learning advanced techniques

QUESTIONS