Trees and More in SQL

Common Table Expressions
PgDay EU 2008

Some Approaches

- External Processing
- Functions and Stored Procedures
- Materialized Path Enumeration
- Nested Set

External Processing

- Pros:
  - Lots of Language Choices
- Cons:
  - Scaling
  - No Relational Operators

Functions and Stored Procedures

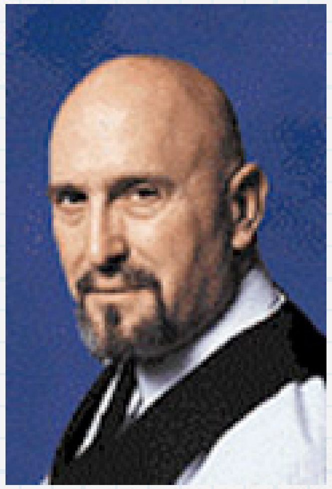
- Pros:
  - Easy to visualize
  - Easy to write
- Cons:
  - Scaling
  - Hard to do relational operators

Materialized Path Enumeration

- Pros:
    - Easy to visualize
- Cons:
    - DDL for each hierarchy
    - Full-table changes on write
    - Hard to do relational operators

Nested Sets

- Pros:
  - Easy to manipulate on SELECT
  - Sounds cool
  - Endorsed by a famous bald guy



- Cons:
  - DDL for each hierarchy
  - Full-table changes on write
  - Hard to do relational operators

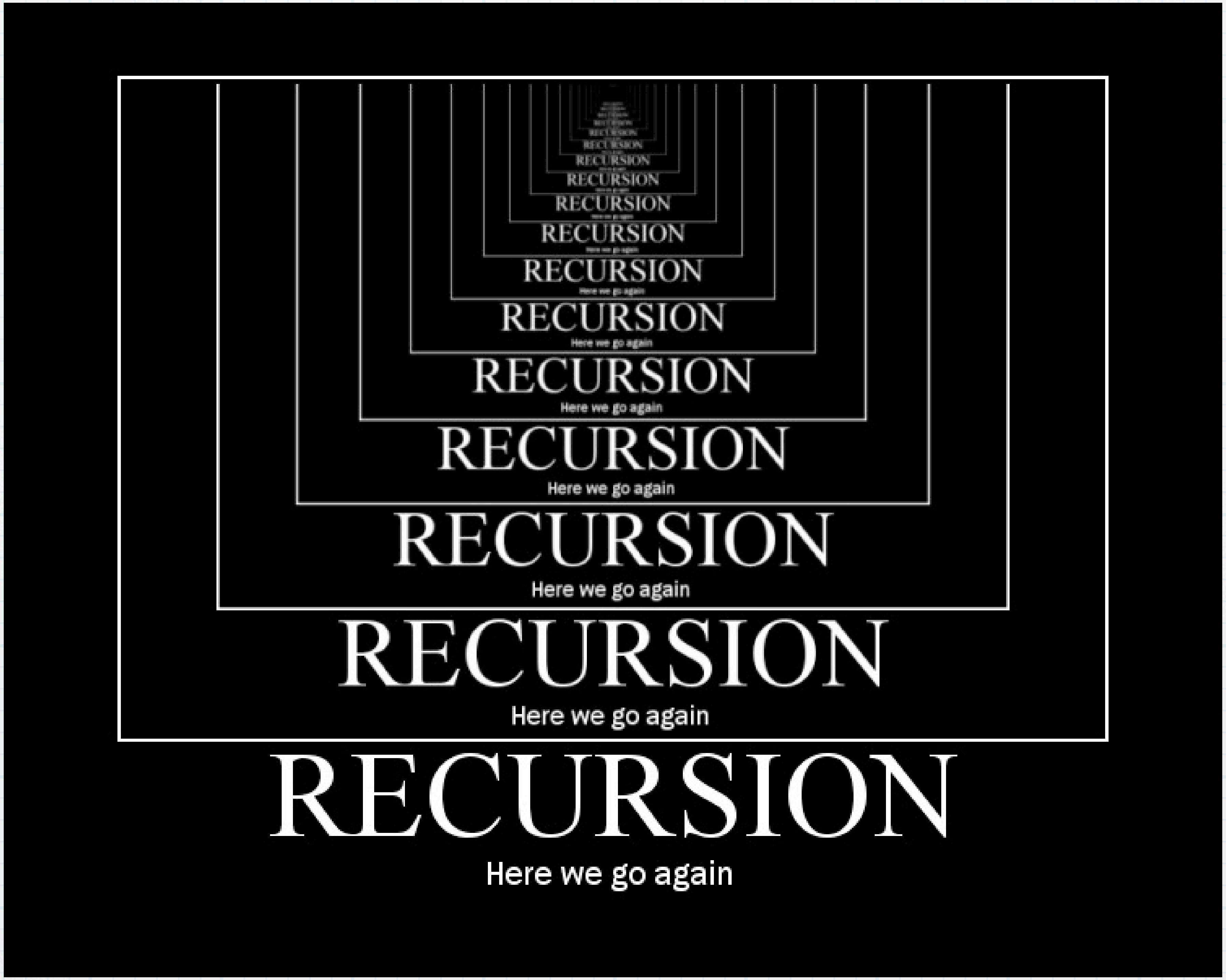
Thanks to:

- The ISO SQL Standards Committee
- Yoshiyuki Asaba
- Ishii Tatsuo
- Jeff Davis
- Gregory Stark
- Tom Lane
- etc., etc., etc.

SQL Standard

- Common Table Expressions (CTE)

Recursion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Here we go again
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Recursion in General

- Initial Condition
- Recursion step
- Termination condition

El List Table

```
CREATE TABLE employee(
    id INTEGER NOT NULL,
    boss_id INTEGER,
    UNIQUE(id, boss_id)/*, etc., etc. */
);

INSERT INTO employee(id, boss_id)
VALUES(1,NULL), /* El capo di tutti capi */
(2,1),(3,1),(4,1),
(5,2),(6,2),(7,2),(8,3),(9,3),(10,4),
(11,5),(12,5),(13,6),(14,7),(15,8),
(1,9);
```

Tree Query Initiation

```
WITH RECURSIVE t(node, path) AS (
   SELECT id, ARRAY[id] FROM employee WHERE boss_id IS NULL
   /* Initiation Step */
UNION ALL
    SELECT e1.id, t.path || ARRAY[e1.id]
    FROM employee e1 JOIN t ON (e1.boss_id = t.node)
    WHERE id NOT IN (t.path)
)
SELECT
    CASE WHEN array_upper(path,1)>1 THEN '+-' ELSE '' END ||
    REPEAT('--', array_upper(path,1)-2) ||
    node AS "Branch"
FROM t
ORDER BY path;
```

Tree Query Recursion

```
WITH RECURSIVE t(node, path) AS (
   SELECT id, ARRAY[id] FROM employee WHERE boss_id IS NULL
UNION ALL
    SELECT e1.id, t.path || ARRAY[e1.id] /* Recursion */
    FROM employee e1 JOIN t ON (e1.boss_id = t.node)
    WHERE id NOT IN (t.path)
)
SELECT
    CASE WHEN array_upper(path,1)>1 THEN '+-' ELSE '' END ||
    REPEAT('--', array_upper(path,1)-2) ||
    node AS "Branch"
FROM t
ORDER BY path;
```

Tree Query Termination

```
WITH RECURSIVE t(node, path) AS (
    SELECT id, ARRAY[id] FROM employee WHERE boss_id IS NULL
UNION ALL
    SELECT e1.id, t.path || ARRAY[e1.id]
    FROM employee e1 JOIN t ON (e1.boss_id = t.node)
    WHERE id NOT IN (t.path) /* Termination Condition */
)
SELECT
    CASE WHEN array_upper(path,1)>1 THEN '+-' ELSE '' END ||
    REPEAT('--', array_upper(path,1)-2) ||
    node AS "Branch"
FROM t
ORDER BY path;
```

Tree Query Display

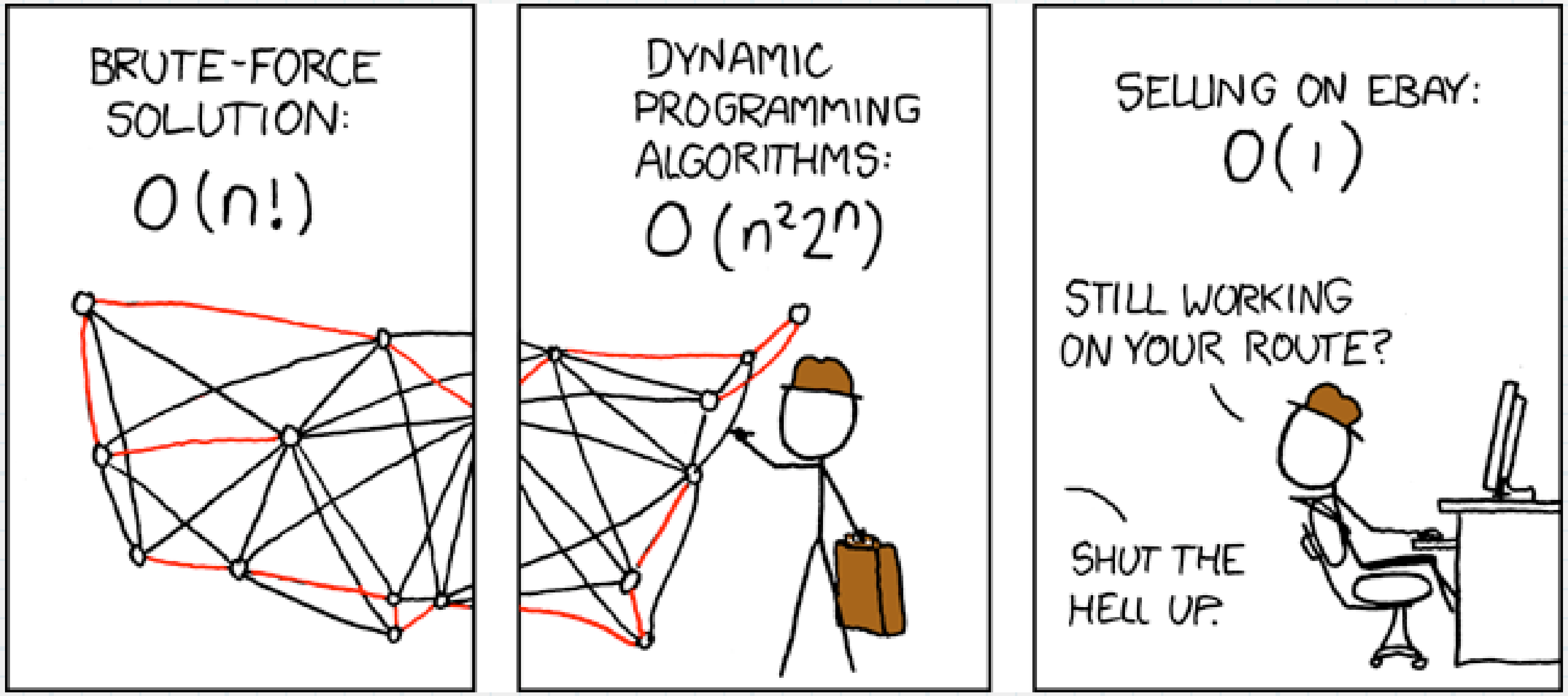
```
WITH RECURSIVE t(node, path) AS (
   SELECT id, ARRAY[id] FROM employee WHERE boss_id IS NULL
UNION ALL
    SELECT e1.id, t.path || ARRAY[e1.id]
    FROM employee e1 JOIN t ON (e1.boss_id = t.node)
    WHERE id NOT IN (t.path)
)
SELECT
    CASE WHEN array_upper(path,1)>1 THEN '+-' ELSE '' END ||
    REPEAT('--', array_upper(path,1)-2) ||
    node AS "Branch" /* Display */
FROM t
ORDER BY path;
```

Tree Query Initiation

```
  Branch
----------
 1
 +-2
 +---5
 +-----11
 +-----12
 +---6
 +-----13
 +---7
 +-----14
 +-3
 +---8
 +-----15
 +---9
 +-4
 +---10
 +-9
(16 rows)
```

Travelling Salesman Problem

Given a number of cities and the costs of travelling from any city to any other city, what is the least-cost round-trip route that visits each city exactly once and then returns to the starting city?



TSP Schema

```
CREATE TABLE pairs (
    from_city TEXT NOT NULL,
    to_city TEXT NOT NULL,
    distance INTEGER NOT NULL,
    PRIMARY KEY(from_city, to_city),
    CHECK (from_city < to_city)
);
```

TSP Data

```
INSERT INTO pairs
VALUES
    ('Bari','Bologna',672),
    ('Bari','Bolzano',939),
    ('Bari','Firenze',723),
    ('Bari','Genova',944),
    ('Bari','Milan',881),
    ('Bari','Napoli',257),
    ('Bari','Palermo',708),
    ('Bari','Reggio Calabria',464),
    ....
```

TSP Program:

Symmetric Setup

```
WITH RECURSIVE both_ways(
    from_city,
    to_city,
    distance
)         /* Working Table */
AS (
    SELECT
        from_city,
        to_city,
        distance
    FROM
        pairs
UNION ALL
    SELECT
        to_city AS "from_city",
        from_city AS "to_city",
        distance
    FROM
        pairs
),
```

TSP Program:

Symmetric Setup

```
WITH RECURSIVE both_ways(
    from_city,
    to_city,
    distance
)
AS (/* Distances One Way */
    SELECT
        from_city,
        to_city,
        distance
    FROM
        pairs
UNION ALL
    SELECT
        to_city AS "from_city",
        from_city AS "to_city",
        distance
    FROM
        pairs
),
```

TSP Program:

Symmetric Setup

```
WITH RECURSIVE both_ways(
    from_city,
    to_city,
    distance
)
AS (
    SELECT
        from_city,
        to_city,
        distance
    FROM
        pairs
UNION ALL /* Distances Other Way */
    SELECT
        to_city AS "from_city",
        from_city AS "to_city",
        distance
    FROM
        pairs
),
```

TSP Program:

Path Initialization Step

```
paths (
    from_city,
    to_city,
    distance,
    path
)
AS (
    SELECT
        from_city,
        to_city,
        distance,
        ARRAY[from_city] AS "path"
    FROM
        both_ways b1
    WHERE
        b1.from_city = 'Roma'
UNION ALL
```

TSP Program:

Path Recursion Step

```
    SELECT
        b2.from_city,
        b2.to_city,
        p.distance + b2.distance,
        p.path || b2.from_city
    FROM
        both_ways b2
    JOIN
        paths p
        ON (
            p.to_city = b2.from_city
        AND
            b2.from_city <> ALL (p.path[
                2:array_upper(p.path,1)
            ]) /* Prevent re-tracing */
        AND
            array_upper(p.path,1) < 6
        )
)
```

TSP Program:

Timely Termination Step

```
    SELECT
        b2.from_city,
        b2.to_city,
        p.distance + b2.distance,
        p.path || b2.from_city
    FROM
        both_ways b2
    JOIN
        paths p
        ON (
            p.to_city = b2.from_city
        AND
            b2.from_city <> ALL (p.path[
                2:array_upper(p.path,1)
            ]) /* Prevent re-tracing */
        AND
            array_upper(p.path,1) < 6 /* Timely Termination */
        )
)
```

TSP Program:

Filter and Display

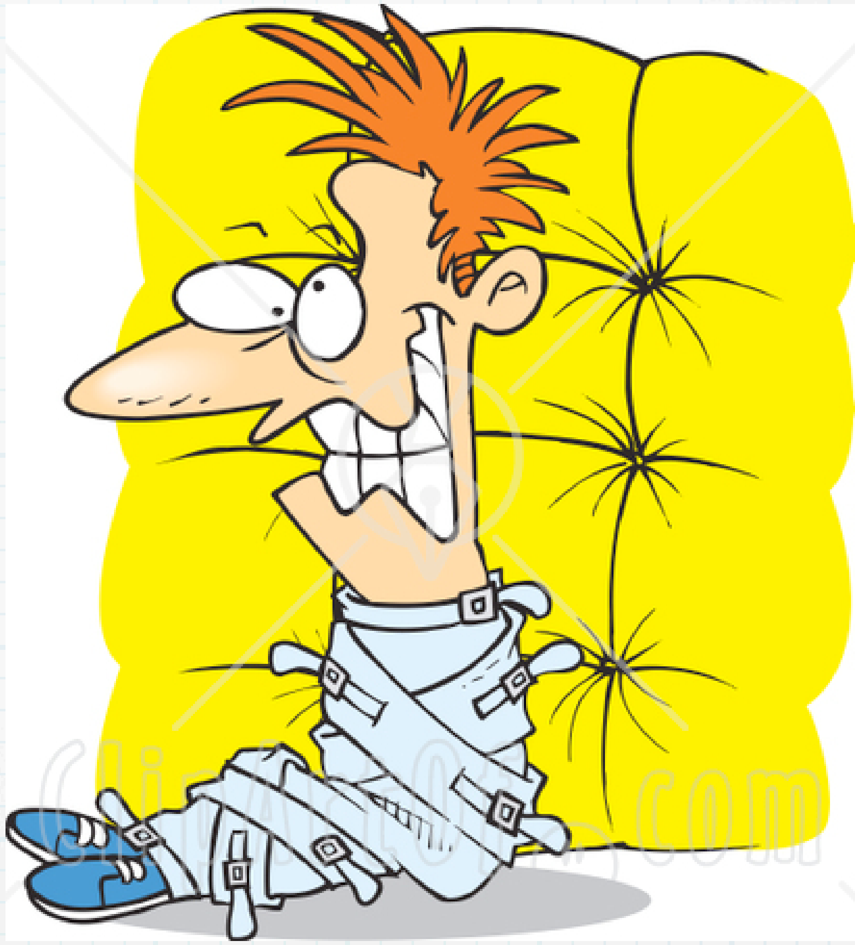
```
SELECT
    path || to_city AS "path",
    distance
FROM
    paths
WHERE
    to_city = 'Roma'
AND
    ARRAY['Milan','Firenze','Napoli'] <@ path
ORDER BY distance, path
LIMIT 1;
```

TSP Program:

Filter and Display

```
davidfetter@tsp=# \i travelling_salesman.sql
               path                | distance
----------------------------------+----------
 {Roma,Firenze,Milan,Napoli,Roma} |     1553
(1 row)

Time: 11679.503 ms
```



Domande?
Commenti?
Camicie di forza?

Mille Grazie!