High Performance SQL with PostgreSQL 8.4

Lists and Recursion and Trees, Oh My!
OSCON 2009

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PGX
POSTGRESQL
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INITECH

T.P.S. REPORT

COVER SHEET

Prepared By:_____Date:_____

Device/Program Type:_____

Product Code:_____Customer:_____

Vendor:_____

Due Date:_____Data Loss:_____

Test Date:_____Target Run Date:_____

Program Run Time:_____Reference Guide:_____

Program Language:_____Number of Error Messages:_____

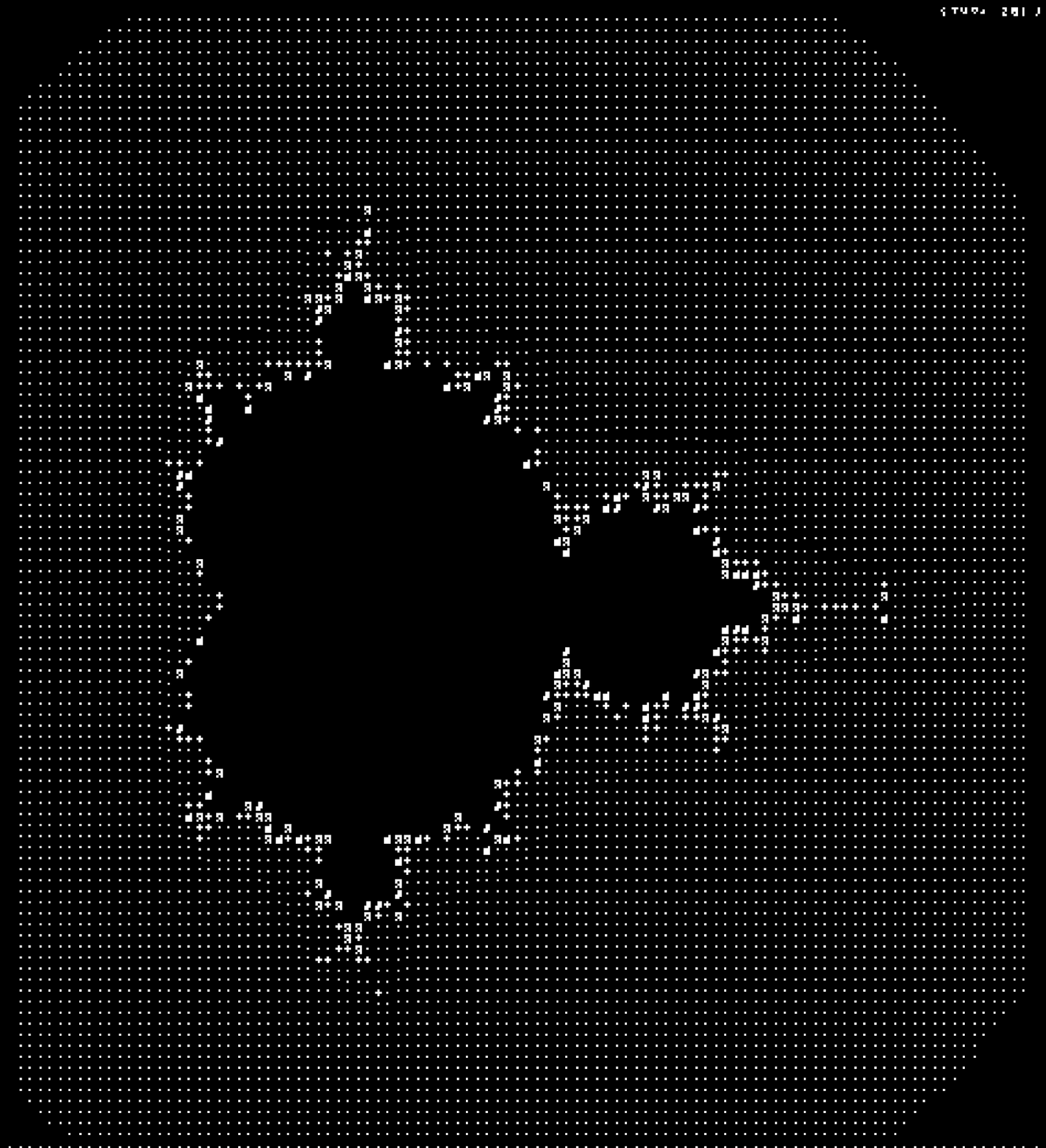
Comments:_____

_____

_____

_____

CONFIDENTIAL



Better, Faster TPS Reports

New!

Reach Outside the Current Row

Better, Faster TPS Reports

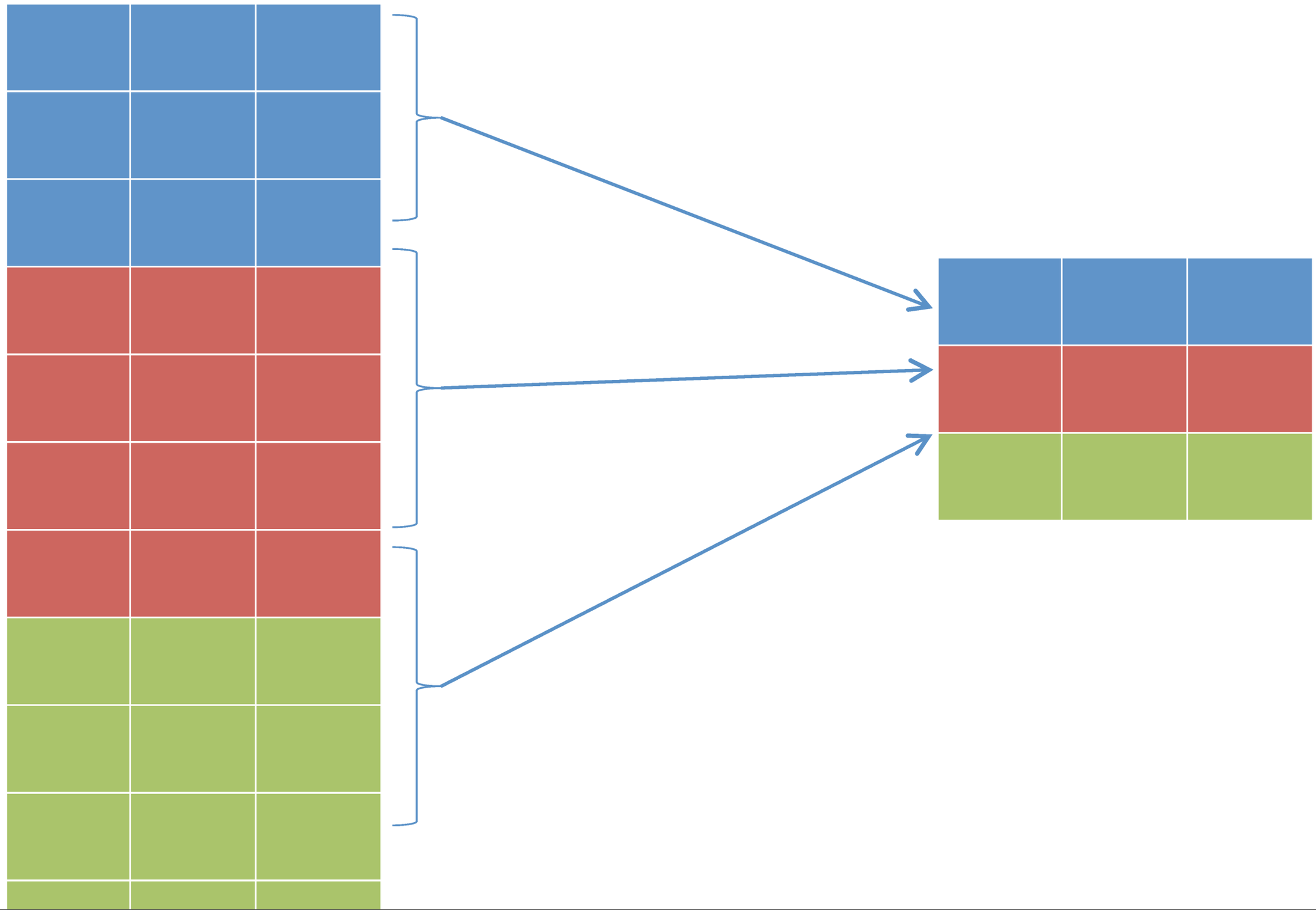
- Windowing Function
  - Operates on a window
  - Returns a value for each row
  - Calculates value from the rows in the window

Better, Faster TPS Reports

- You can use…
  - New window functions
  - Existing aggregate functions
  - User-defined window functions
  - User-defined aggregate functions

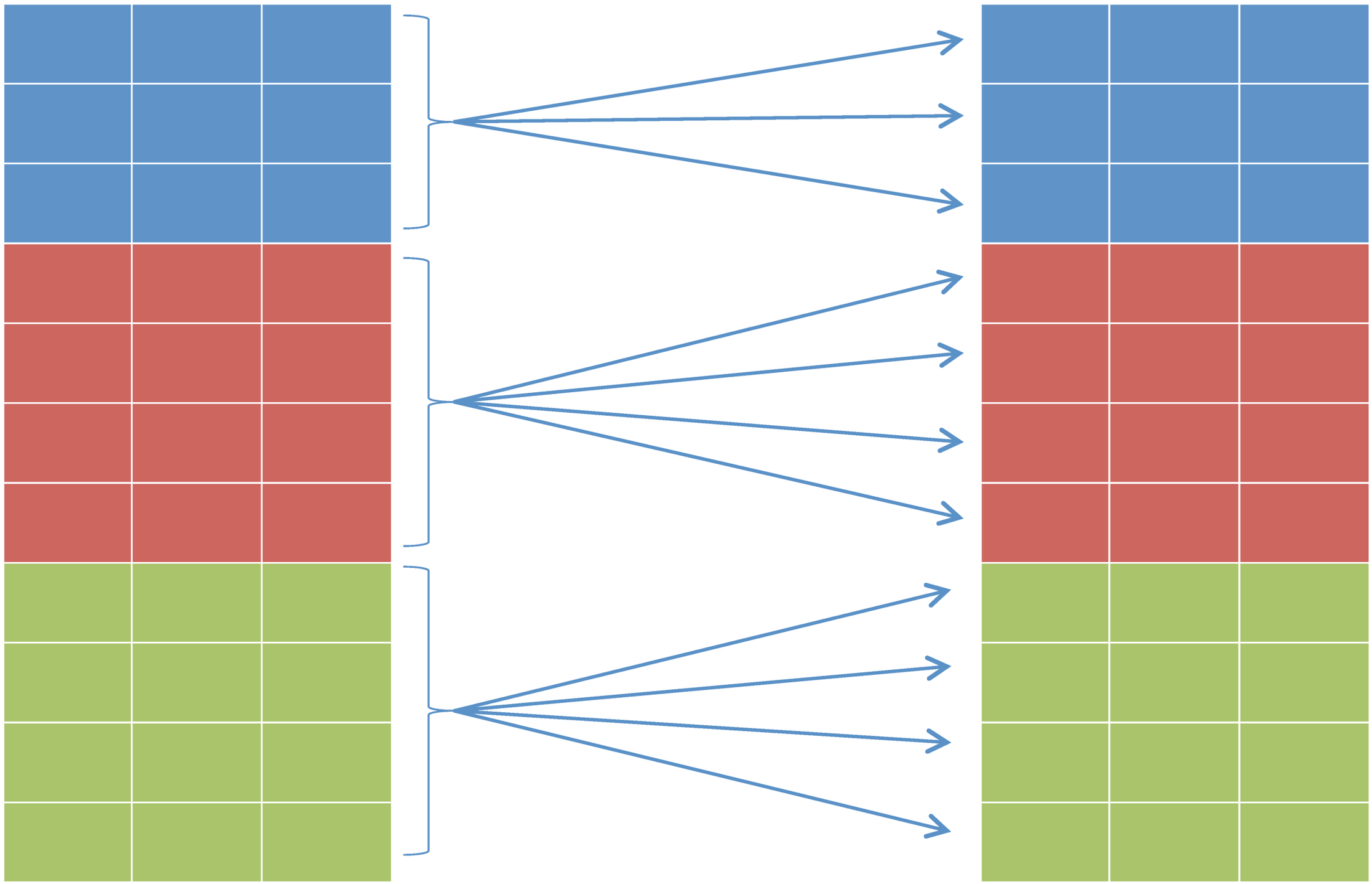
Better, Faster TPS Reports

[Aggregates] SELECT key, SUM(val) FROM tbl GROUP BY key;



Better, Faster TPS Reports

[Windowing Functions] SELECT key, SUM(val) OVER (PARTITION BY key) FROM tbl;



ROW_NUMBER (Before)

```
SELECT
    e1.empno,
    e1.depname,
    e1.salary,
    count(*) AS row_number
FROM
    empsalary e1
JOIN
    empsalary e2
    ON (e1.empno < e2.empno)
GROUP BY e1.empno, e1.depname, e1.salary
ORDER BY e1.empno DESC;
```

ROW_NUMBER (Before)

OOPS!

empno	depname	salary	row_number
8	develop	6000	1
6	sales	5500	2
11	develop	5200	4
10	develop	5200	4
1	sales	5000	5
3	sales	4800	7
4	sales	4800	7
9	develop	4500	8
7	develop	4200	9
2	personnel	3900	10
5	personnel	3500	11

(11 rows)

ROW_NUMBER (After)

```
SELECT
    empno,
    depname,
    salary,
    row_number() OVER (
        ORDER BY salary DESC NULLS LAST
    )
FROM
    empsalary
ORDER BY salary DESC;
```

ROW_NUMBER (After)

Yippee!

empno	depname	salary	row_number
8	develop	6000	1
6	sales	5500	2
10	develop	5200	3
11	develop	5200	4
1	sales	5000	5
3	sales	4800	6
4	sales	4800	7
9	develop	4500	8
7	develop	4200	9
2	personnel	3900	10
5	personnel	3500	11

(11 rows)

Built-in Windowing Functions

- row_number()
- rank()
- dense_rank()
- percent_rank()
- cume_dist()
- ntile()
- lag()
- lead()
- first_value()
- last_value()
- nth_value()

Generate Points

```
WITH RECURSIVE x(i)
AS (
   VALUES(0)
UNION ALL
   SELECT i + 1

   FROM X
   WHERE i < 101
),
```

Generate Points

```
Z(Ix, Iy, Cx, Cy, X, Y, I)
AS (
        SELECT Ix, Iy,
               X::float, Y::float,
               X::float, Y::float,
               0
        FROM
```

Generate Points

```
(SELECT -2.2 + 0.031 * i, i
      FROM x) AS xgen(x,ix)
CROSS JOIN
     (SELECT -1.5 + 0.031 * i, i
      FROM x) AS ygen(y,iy)
```

Generate Points

UNION ALL

Generate Points

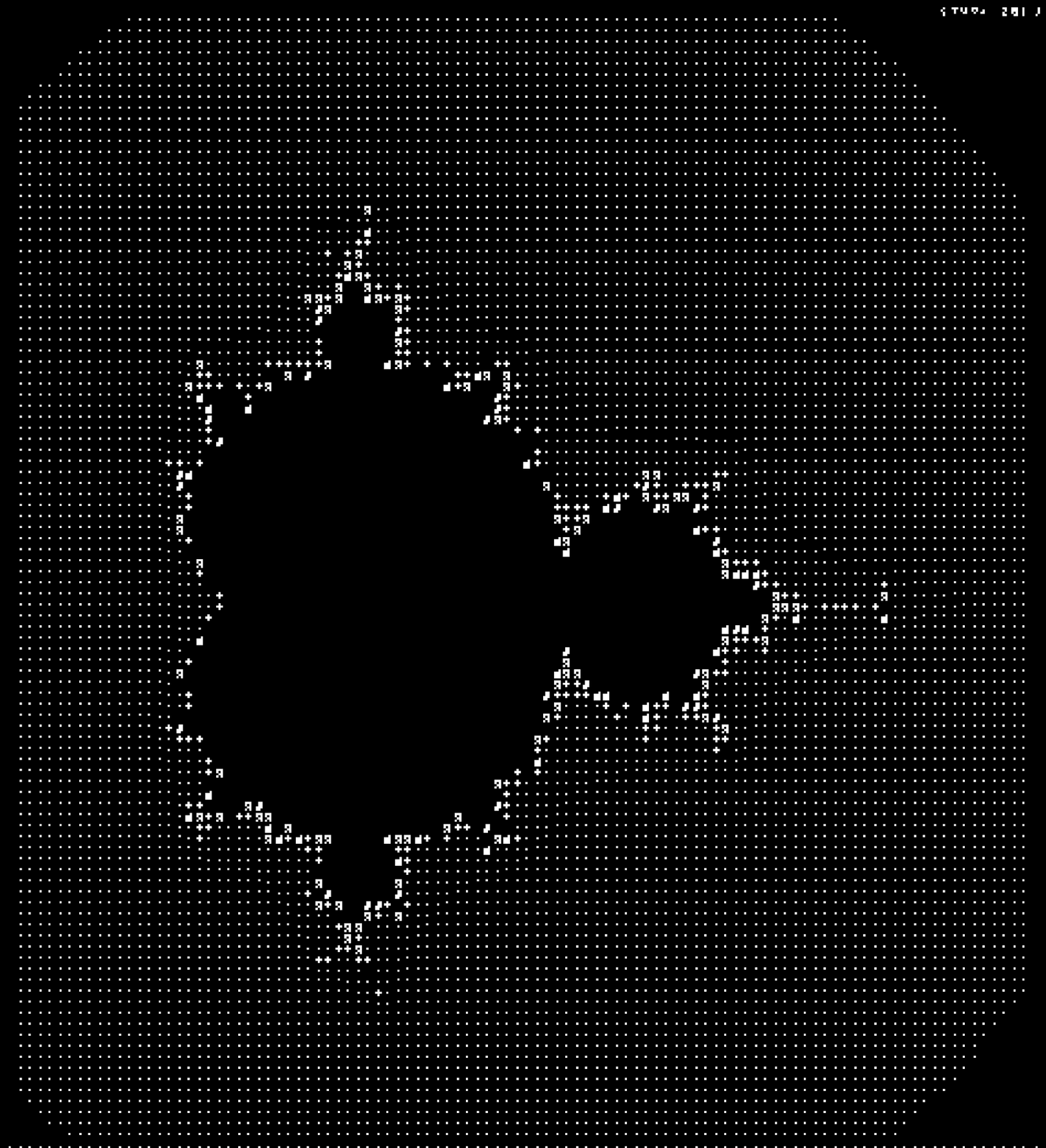
```
SELECT
        Ix, Iy, Cx, Cy,
        X * X - Y * Y + Cx AS X,
        Y * X * 2 + Cy,
        I + 1
    FROM Z
    WHERE X * X + Y * Y < 16.0
    AND I < 27
),
```

Choose Some

```
Zt (Ix, Iy, I) AS (
     SELECT Ix, Iy, MAX(I) AS I
     FROM Z
     GROUP BY Iy, Ix
     ORDER BY Iy, Ix
)
```

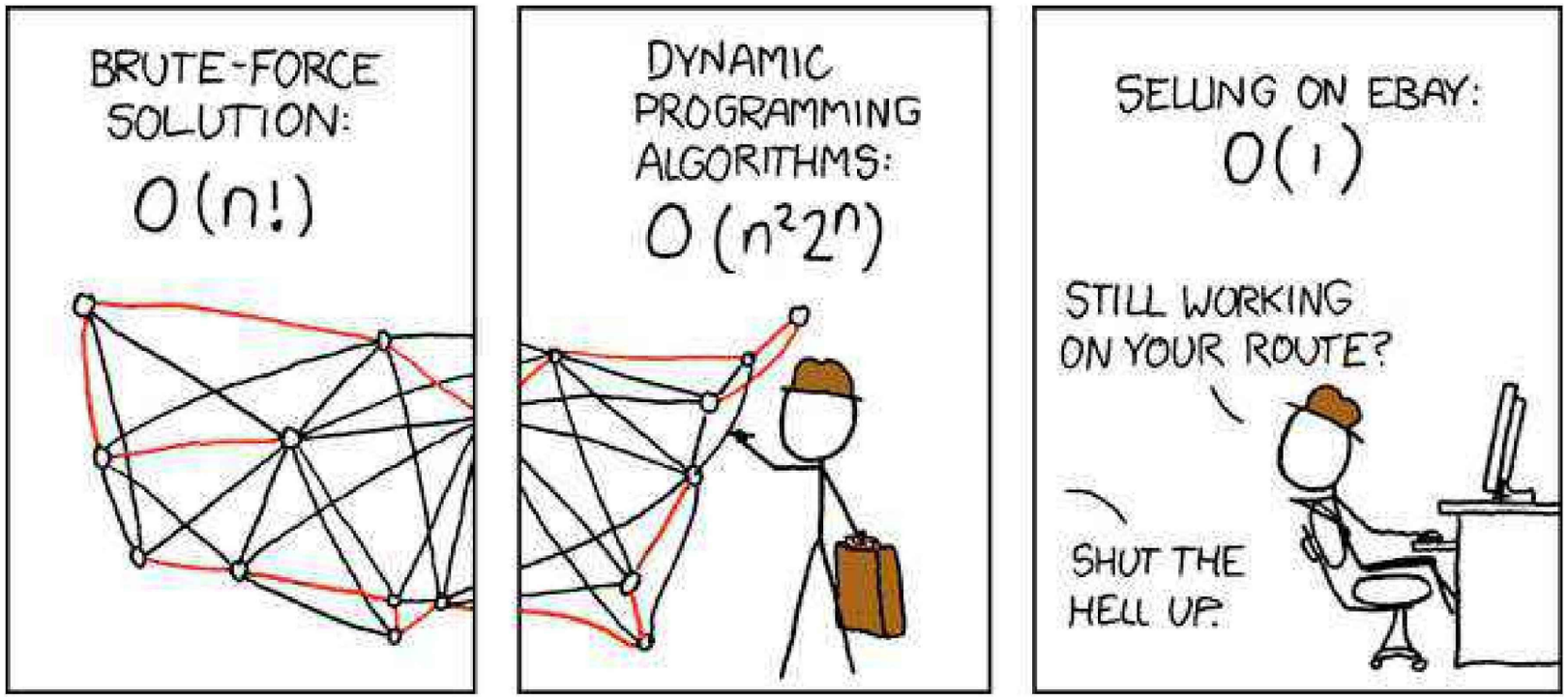
Display Them

```
SELECT array_to_string(
   array_agg(
      SUBSTRING(
         ' .,,,-----++++%%%%@@@@#### ',
         GREATEST(I,1)
   ),''
)
FROM Zt
GROUP BY Iy
ORDER BY Iy;
```



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
```

Who Posts Most?

Who

```
CREATE TABLE forum_users (
  user_name TEXT NOT NULL,
  CHECK(user_name = trim(user_name)),
  user_id SERIAL UNIQUE
);

CREATE UNIQUE INDEX forum_user_user_name_unique
  ON forum_users(lower(user_name));

INSERT INTO forum_users (user_name)
VALUES
  ('Tom Lane'), ('Robert Haas'), ('Alvaro Herrera'), ('Dave Page'),
  ('Heikki Linnakangas'), ('Magnus Hagander'), ('Gregory Stark'),
  ('Josh Berkus'), ('David Fetter'), ('Benjamin Reed');
```

Posts

```
CREATE TABLE message (
  message_id INTEGER PRIMARY KEY,
  parent_id INTEGER
    REFERENCES message(message_id),
  message_text TEXT NOT NULL,
  forum_user_id INTEGER
    NOT NULL REFERENCES forum_users(user_id)
);
```

Add some posts

```
INSERT INTO message
WITH RECURSIVE m(
  message_id,
  parent_id,
  message_text,
  forum_user_id)
AS (
  VALUES(1, NULL::integer, md5(random()::text),1)
```

Add some posts

UNION ALL

Add some posts

```
SELECT
  message_id+1,
  CASE
    WHEN random() >= .5 THEN NULL
    ELSE FLOOR(random()*message_id)+1
    END::integer,
    md5(random()::text),
    floor(random() * 10)::integer +1
  FROM m
  WHERE message_id < 1001
)
SELECT * FROM m;
```

WELL?!?

Patience :)

Find the fr1st ps0t

```
WITH RECURSIVE t1 AS (
  SELECT
    /* First message in the thread is the thread ID */
    message_id AS thread_id,
    message_id,
    parent_id,
    forum_user_id,
    ARRAY[message_id] AS path
FROM message
WHERE parent_id IS NULL
```

Find the Next Ones

UNION ALL

Find the Next Ones

```
SELECT
   t1.thread_id,
   m.message_id,
   m.parent_id,
   m.forum_user_id,
   t1.path || m.message_id
  FROM message m
  JOIN t1 ON
   (t1.message_id = m.parent_id)
),
```

Count Posters in Each Thread

```
t2 AS (
   SELECT
      thread_id,
      forum_user_id,
      count(*) AS reply_count
   FROM t1
   GROUP BY thread_id, forum_user_id
   ORDER BY thread_id, count(*)
),
```

Find the Top Posters

```
t3 AS (
   SELECT thread_id,
   max(reply_count) AS reply_count
   FROM t2
   GROUP BY thread_id
)
```

Show Them :)

```
SELECT t2.thread_id, f.user_name, t3.reply_count
FROM t2
JOIN t3 USING (thread_id, reply_count)
JOIN forum_users f ON (f.user_id = t2.forum_user_id)
WHERE reply_count > 3
ORDER BY reply_count DESC;
```

Top Posters :)

```
 thread_id |     user_name      | reply_count
-----------+--------------------+-------------
         1 | Tom Lane           |           9
         1 | Gregory Stark      |           9
        82 | Magnus Hagander    |           5
       108 | Dave Page          |           4
         9 | Josh Berkus        |           4
(5 rows)
```

OBTW

With CTE and Windowing, SQL is Turing Complete.

Cyclic Tag System

```
The productions are encoded in the table "p" as follows:
   "iter" is the production number;
   "rnum" is the index of the bit;
   "tag" is the bit value.

This example uses the productions:
     110 01 0000

The initial state is encoded in the non-recursive union arm,
in this case just '1'

The (r.iter % n) subexpression encodes the number of
productions, which can be greater than the size of table "p",
because empty productions are not included in the table.
```

Cyclic Tag System

```
Parameters:
     the content of "p"
     the content of the non-recursive branch
     the 3 in (r.iter % 3)

"p" encodes the production rules;  the non-recursive branch is
the initial state, and the 3 is the number of rules

The result at each level is a bitstring encoded as 1 bit per
row, with rnum as the index of the bit number.

At each iteration, bit 0 is removed, the remaining bits
shifted up one, and if and only if bit 0 was a 1, the content
of the current production rule is appended at the end of the
string.
```

Proof:

Construct a Cyclic Tag System with CTEs and Windowing.

Proof:

```
WITH RECURSIVE
p(iter,rnum,tag) AS (
    VALUES (0,0,1),(0,1,1),(0,2,0),
           (1,0,0),(1,1,1),
           (2,0,0),(2,1,0),(2,2,0),(2,3,0)
),
```

Proof:

```
r(iter,rnum,tag) AS (
    VALUES (0,0,1)
UNION ALL
    SELECT r.iter+1,
           CASE
               WHEN r.rnum=0 THEN p.rnum + max(r.rnum) OVER ()
               ELSE r.rnum-1
           END,
           CASE
               WHEN r.rnum=0 THEN p.tag
               ELSE r.tag
           END
    FROM
        r
    LEFT JOIN p
        ON (r.rnum=0 and r.tag=1 and p.iter=(r.iter % 3))
    WHERE
        r.rnum>0
    OR p.iter IS NOT NULL
)
```

Proof:

```
SELECT iter, rnum, tag
FROM r
ORDER BY iter, rnum;
```

Thanks

Andrew (RhodiumToad) Gierth

Questions?

Comments?

Straitjackets?

Thank You!

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