PA036: DB Project
1. PostgreSQL

Vlastislav Dohnal

Relational DBMS

- PostgreSQL
  - open-source relational database management system
  - ver. 16 – docs
- Accessing DB
  - a command-line client: psql
- Benchmarking DB
  - a command-line tool: pgbench

Query Plan

- command EXPLAIN
  - shows how a database will execute a query

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 7000;
                      QUERY PLAN
------------------------------------------------------------
Seq Scan on tenk1 (cost=0.00..483.00 rows=7001 width=244)
   Filter: (unique1 < 7000)
```

```
EXPLAIN SELECT * FROM tenk1 WHERE unique1 < 100;

                            QUERY PLAN
-----------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=5.07..229.20 rows=101 width=244)
   Recheck Cond: (unique1 < 100)
   ->  Bitmap Index Scan on tenk1_unique1  (cost=0.00..5.04 rows=101 width=0)
         Index Cond: (unique1 < 100)
```

Query Plan (cont.)

```
EXPLAIN SELECT * FROM tenk1 t1, tenk2 t2
        WHERE t1.unique1 < 100 AND t1.unique2 = t2.unique2;

                                   QUERY PLAN
----------------------------------------------------------------------------
 Hash Join  (cost=230.47..713.98 rows=101 width=488)
   Hash Cond: (t2.unique2 = t1.unique2)
   ->  Seq Scan on tenk2 t2 (cost=0.00..445.00 rows=10000 width=244)
   ->  Hash  (cost=229.20..229.20 rows=101 width=244)
         ->  Bitmap Heap Scan on tenk1 t1
                                        (cost=5.07..229.20 rows=101 width=244)
               Recheck Cond: (unique1 < 100)
               ->  Bitmap Index Scan on tenk1_unique1
                                            (cost=0.00..5.04 rows=101 width=0)
                     Index Cond: (unique1 < 100)
```

Query Plan (cont.)

- Add analyze to show real execution times

```
EXPLAIN ANALYZE SELECT * FROM tenk1
                WHERE unique1 < 100 AND unique2 > 9000 LIMIT 2;

                               QUERY PLAN
------------------------------------------------------------------------------
 Limit  (cost=0.29..14.71 rows=2 width=244)
                        (actual time=0.177..0.249 rows=2 loops=1)
   ->  Index Scan using tenk1_unique2 on tenk1
                        (cost=0.29..72.42 rows=10 width=244)
                        (actual time=0.174..0.244 rows=2 loops=1)
         Index Cond: (unique2 > 9000)
         Filter: (unique1 < 100)
         Rows Removed by Filter: 287
 Planning time: 0.096 ms
 Execution time: 0.336 ms
```

Planner may show discrepancy in the number of rows

It may signal inefficiency of filter.

If planner is wrong in estimates, try to update statistics – vacuum command.

Query Plan (cont.)

- Beware of data modifying queries under inspection -> use transactions

```
BEGIN;
EXPLAIN ANALYZE UPDATE tenk1 SET hundred = hundred + 1 WHERE unique1 < 100;
                            QUERY PLAN
------------------------------------------------------------------------------
 Update on tenk1  (cost=5.08..230.08 rows=0 width=0)
                                 (actual time=3.791..3.792 rows=0 loops=1)
   ->  Bitmap Heap Scan on tenk1  (cost=5.08..230.08 rows=102 width=10)
                                 (actual time=0.069..0.513 rows=100 loops=1)
         Recheck Cond: (unique1 < 100)
         Heap Blocks: exact=90
         ->  Bitmap Index Scan on tenk1_unique1
                                 (cost=0.00..5.05 rows=102 width=0)
                                 (actual time=0.036..0.037 rows=300 loops=1)
               Index Cond: (unique1 < 100)
 Planning Time: 0.113 ms
 Execution Time: 3.850 ms
ROLLBACK;
```

Query Plan (cont.)

- Add buffers – shows how much data was read

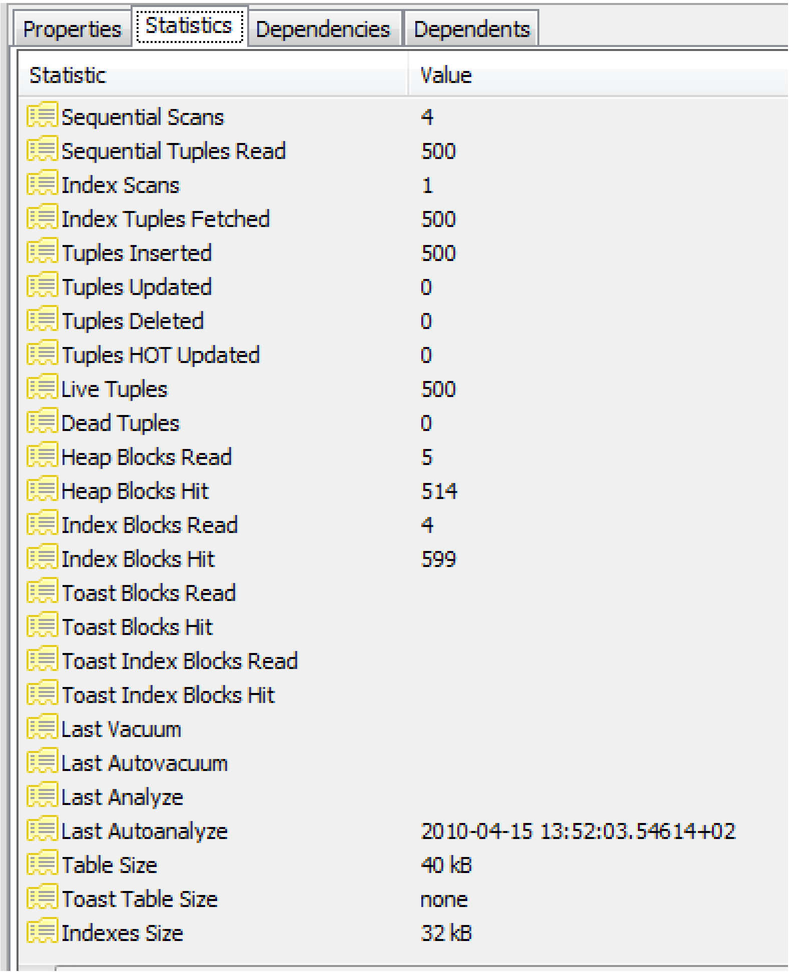
```
EXPLAIN (ANALYZE, BUFFERS) SELECT * FROM tenk1
                                     WHERE unique1 < 100 AND unique2 > 9000;
                             QUERY PLAN
------------------------------------------------------------------------------
 Bitmap Heap Scan on tenk1  (cost=25.08..60.21 rows=10 width=244)
                                     (actual time=0.323..0.342 rows=10 loops=1)
   Recheck Cond: ((unique1 < 100) AND (unique2 > 9000))
   Buffers: shared hit=15
   ->  BitmapAnd  (cost=25.08..25.08 rows=10 width=0)
                                     (actual time=0.309..0.309 rows=0 loops=1)
         Buffers: shared hit=7
         ->  Bitmap Index Scan on tenk1_unique1
                                     (cost=0.00..5.04 rows=101 width=0)
                                     (actual time=0.043..0.043 rows=100 loops=1)
               Index Cond: (unique1 < 100)
               Buffers: shared hit=2
         ->  Bitmap Index Scan on tenk1_unique2
                                     (cost=0.00..19.78 rows=999 width=0)
                                     (actual time=0.227..0.227 rows=999 loops=1)
               Index Cond: (unique2 > 9000)
               Buffers: shared hit=5
 Planning time: 0.088 ms
 Execution time: 0.423 ms
```

Query Rewriting

- Modifying the query text to eliminate unnecessary operations
  - Keeping the result identical!!!
- Techniques
  - Use of indexes
    - attribute selection, inclusion of attributes, clustering the table by an index
  - Elimination unnecessary ops (DISTINCT, GROUP BY, …)
  - (Correlated) subqueries
    - changing subquery to a join, “with” clause
  - Temporary tables
  - Incorrect use of having
  - Materialized views and its maintenance

Statistics in PostgreSQL

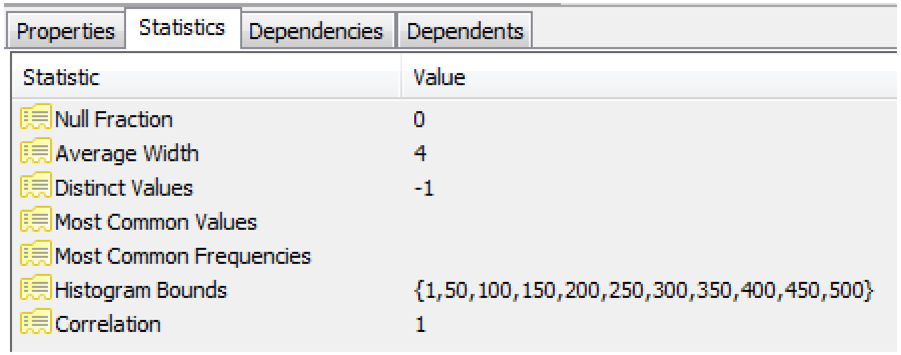
- Relation hotel



Statistic	Value
Sequential Scans	4
Sequential Tuples Read	500
Index Scans	1
Index Tuples Fetched	500
Tuples Inserted	500
Tuples Updated	0
Tuples Deleted	0
Tuples HOT Updated	0
Live Tuples	500
Dead Tuples	0
Heap Blocks Read	5
Heap Blocks Hit	514
Index Blocks Read	4
Index Blocks Hit	599
Toast Blocks Read	
Toast Blocks Hit	
Toast Index Blocks Read	
Toast Index Blocks Hit	
Last Vacuum	
Last Autovacuum	
Last Analyze	
Last Autoanalyze	2010-04-15 13:52:03.54614+02
Table Size	40 kB
Toast Table Size	none
Indexes Size	32 kB

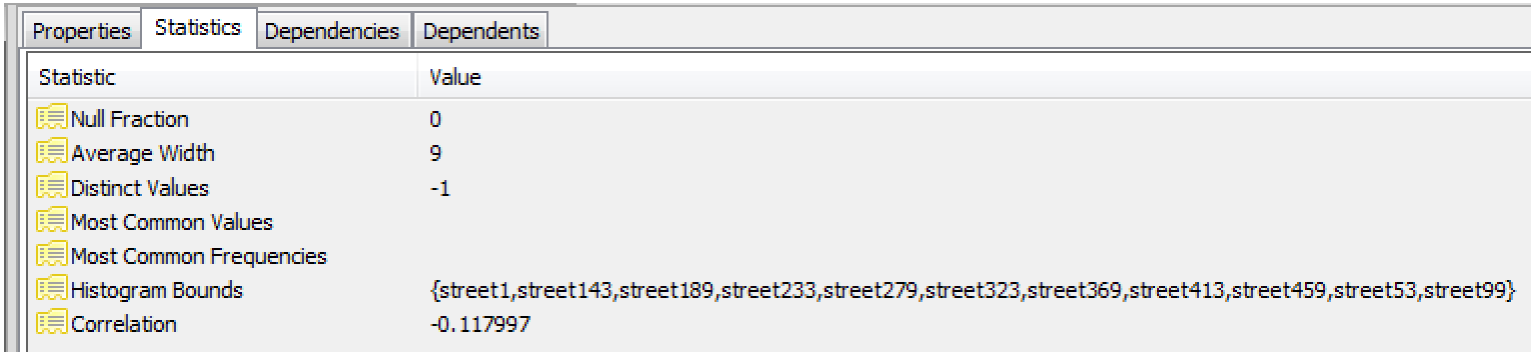
Statistics in PostgreSQL

- Attribute hotel.id



Statistic	Value
Null Fraction	0
Average Width	4
Distinct Values	-1
Most Common Values	
Most Common Frequencies	
Histogram Bounds	{1,50,100,150,200,250,300,350,400,450,500}
Correlation	1

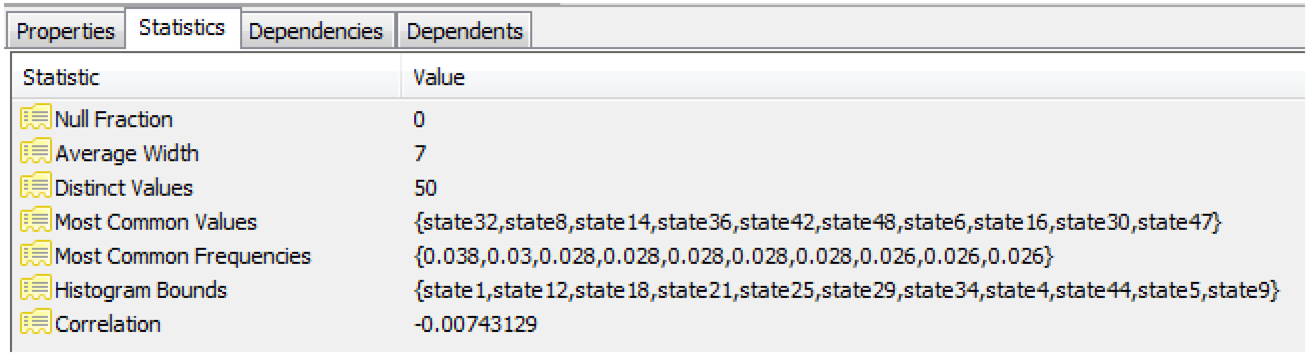
- Attribute hotel.name



Statistic	Value
Null Fraction	0
Average Width	9
Distinct Values	-1
Most Common Values	
Most Common Frequencies	
Histogram Bounds	{street1,street143,street189,street233,street279,street323,street369,street413,street459,street53,street99}
Correlation	-0.117997

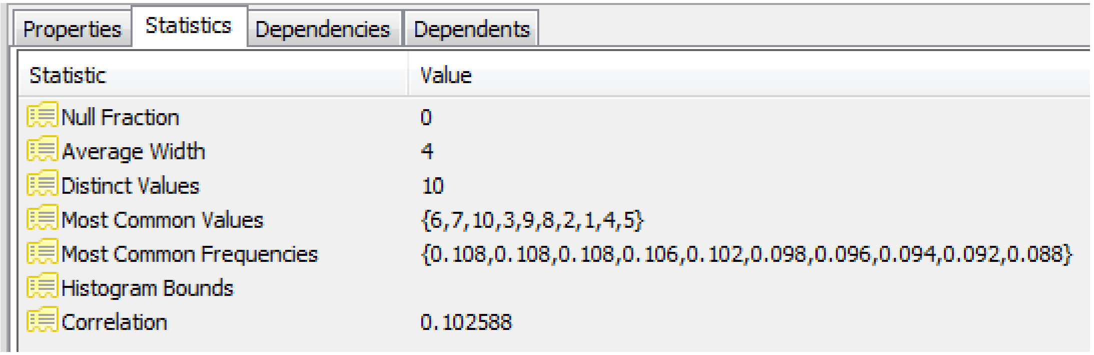
Statistics in PostgreSQL

- Attribute hotel.state



Statistic	Value
Null Fraction	0
Average Width	7
Distinct Values	50
Most Common Values	{state32,state8,state14,state36,state42,state48,state6,state16,state30,state47}
Most Common Frequencies	{0.038,0.03,0.028,0.028,0.028,0.028,0.028,0.026,0.026,0.026}
Histogram Bounds	{state1,state12,state18,state21,state25,state29,state34,state4,state44,state5,state9}
Correlation	-0.00743129

- Attribute hotel.distance_to_center



Statistic	Value
Null Fraction	0
Average Width	4
Distinct Values	10
Most Common Values	{6,7,10,3,9,8,2,1,4,5}
Most Common Frequencies	{0.108,0.108,0.108,0.106,0.102,0.098,0.096,0.094,0.092,0.088}
Histogram Bounds	
Correlation	0.102588

Indexes in PostgreSQL

- Index types in docs
  - B-tree, Hash
  - GiST, SP-GiST
    - for several two-dimensional geometric data types,
    - supports “nearest neighbors” queries
  - GIN
    - inverted file, for indexing arrays
  - BRIN (Block Range Index)
    - stores summaries about the values stored in consecutive physical block ranges of a table, good for values well-correlated with the physical order of the table rows

Indexes in PostgreSQL (cont.)

- Multicolumn indexes
  - Mind the order of attributes
- Expression based indexes
  - Evaluate a function to be stored in the index
- Partial indexes
  - Index only a subset of rows

Transactions in Pg

- Transactions (a sequence of work done all or none)
  - ACID properties
  - Control commands:
    - BEGIN - Starts a new transaction.
    - COMMIT - Saves all changes made in the transaction permanently.
    - ROLLBACK - Undoes all changes made in the current transaction.

Transactions in Pg (cont.)

- Transactions
  - Control commands within a transaction:
    - SAVEPOINT <name> - Creates a checkpoint inside a transaction to which you can ROLLBACK.
    - ROLLBACK TO SAVEPOINT <name> - Undoes changes made after a specific savepoint.
- Isolation level
  - determines how transactions interact with each other

Isolation Levels in Pg

- Command:
  - BEGIN;
  - SET TRANSACTION ISOLATION LEVEL …;
- Levels:
  - Read uncommitted
  - Read committed (default)
  - Repeatable read
  - Serializable

Isolation Levels in Pg (cont.)

- Read uncommitted (fastest, unsafe)
  - Transactions can read uncommitted changes from other transactions
- Read committed
  - A transaction sees only committed changes from other transactions.
  - Each query in the transaction gets a fresh snapshot of the database.
- Repeatable read
  - A transaction sees a consistent snapshot throughout its execution.
  - Prevents non-repeatable reads but may still allow phantom reads.
- Serializable (slowest, correct)
  - Transactions are executed in a way that ensures they behave as if they were executed sequentially.
  - Prevents dirty reads, non-repeatable reads, and phantom reads.

Isolation Levels in Pg (cont.)

- Any change to data (INSERT, UPDATE, DELETE) creates a “lock”
  - Lock is release on COMMIT or ROLLBACK.
- View locks:
  - SELECT * FROM pg_locks WHERE granted = true;
- Typically, we are happy to let handled by Pg automatically.

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Isolation Levels in Pg (cont.)

- Row-level locks
  - SELECT… FROM… FOR [UPDATE|SHARE]
  - FOR UPDATE
    - Locks selected rows, preventing other transactions from modifying them.
  - FOR SHARE
    - Allows concurrent reads but prevents updates/deletes.

Isolation Levels in Pg (cont.)

- Table-level locks – controls access to the whole table
  - ACCESS SHARE – Default lock for SELECT statements (allows concurrent reads).
  - ROW SHARE – Acquired by SELECT ... FOR UPDATE or FOR SHARE.
  - ROW EXCLUSIVE – Used by INSERT, UPDATE, and DELETE.
  - SHARE – Prevents writes but allows concurrent reads.
  - SHARE ROW EXCLUSIVE – Prevents concurrent writes and some reads.
  - EXCLUSIVE – Allows only the locking transaction to modify the table.
  - ACCESS EXCLUSIVE – Blocks all reads and writes (used by ALTER TABLE, DROP TABLE).

- That’ all, folks.