Query Parallelism In PostgreSQL

Expectations and Opportunities

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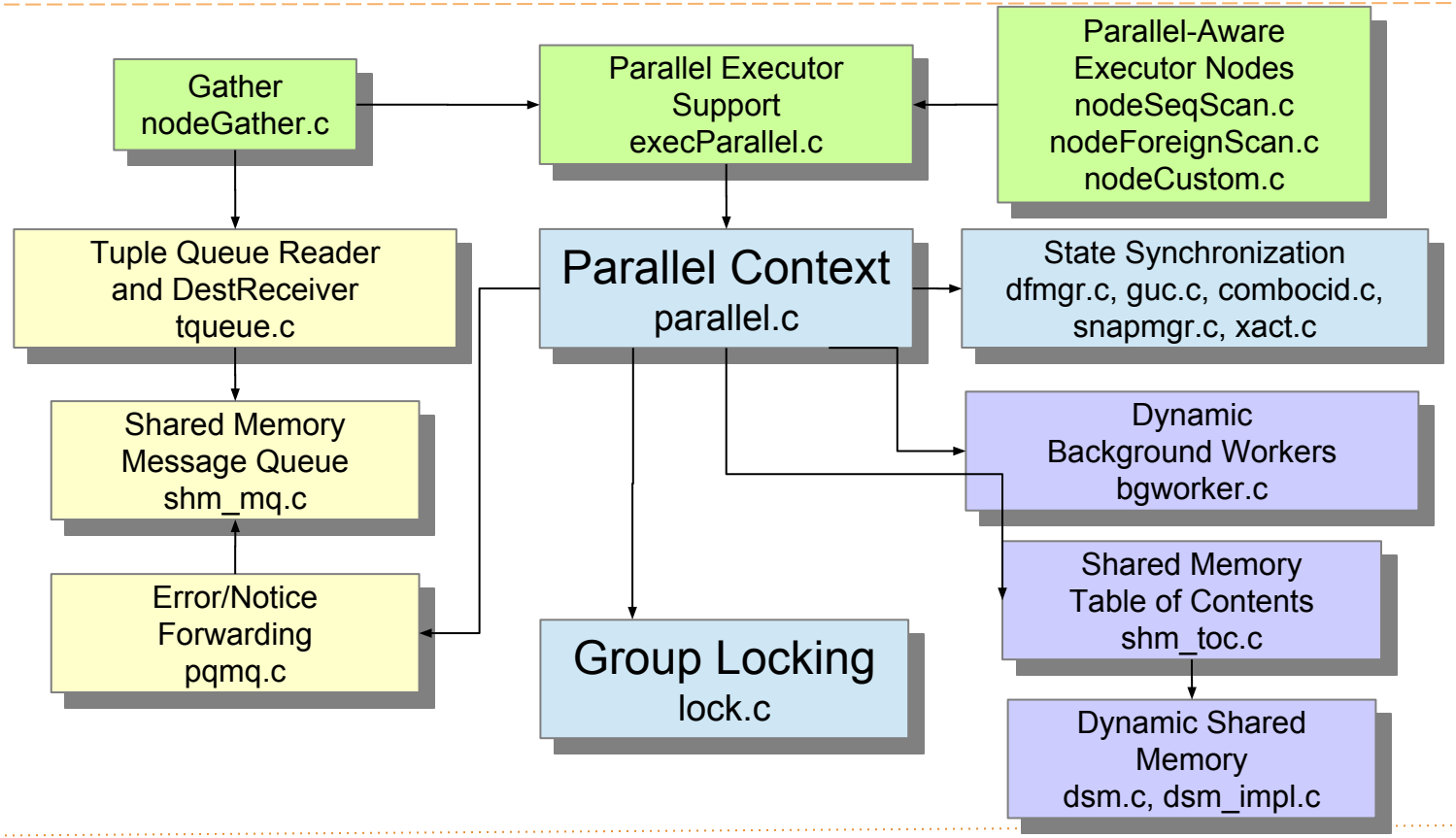
Overview

- Infrastructure for parallelism
- Intra-query parallelism in v9.6
  - Parallel aware executor nodes
  - Performance on TPC-H
  - Limitations
- Parallelism enhancements in v10
  - More executor-nodes
  - Performance on TPC-H
- Take away

Overview of parallel query infrastructure

- Groundwork for parallelism
  - Dynamic background workers
  - Dynamic shared memory
  - Shared messaging capabilities
  - Group locking
  - Parallel context
- Intra-query parallel support
  - Parallel executor
  - Parallel-aware nodes
    - seq scan,
    - joins, and
    - aggregates

Parallel Query Architecture



Groundwork for parallelism

- Dynamic background worker (shm_mq)
  - Postmaster can launch the background worker processes at run time
- Dynamic shared memory
  - Allocate a chunk of memory that can be shared among co-operating processes
  - Shared memory table of contents
    - A simple scheme for carving DSM into numbered chunks
- Shared messaging capabilities
  - Shared memory message queue
    - For error/notice forwarding
    - Tuple queue reader and DestReceiver

Groundwork for parallelism

- Parallel context
  - Core toolkit for parallel operations
  - Launch a number of workers, establish "useful" state, run C code you specify and ensure timely shutdown.
- State synchronization
  - To ensure same GUC values, libraries, and transactions with same snapshot across workers
- Group locking
  - To solve the issue of undetected deadlock
  - Leader and its workers are treated as one entity for locking purposes

Intra-query parallel support

- Parallel executor support
  - Execute a plan by a set of worker
  - Pass instrumentation information to each worker
- Parallel aware executor nodes
  - Different behaviour when run in parallel or otherwise
- Gather
  - Collect results across all workers and merge them into a single result stream

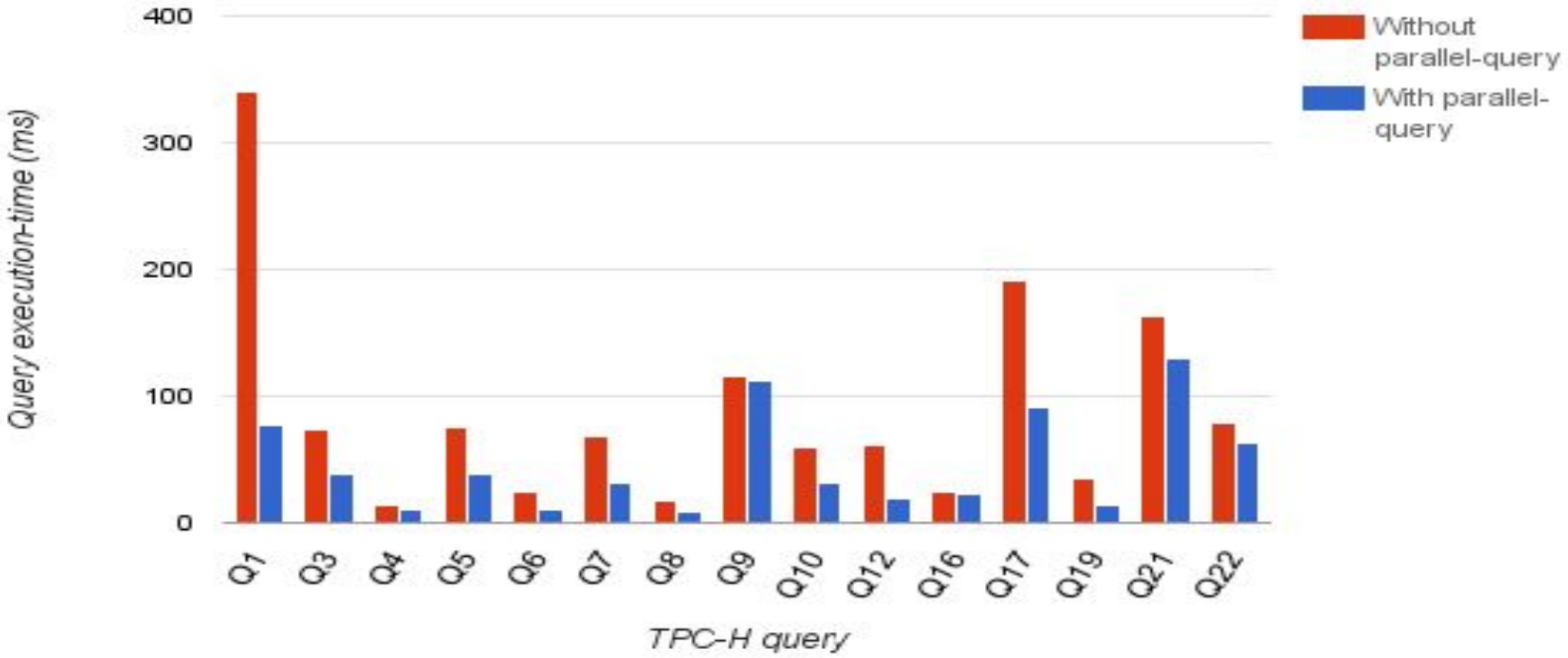
Intra-query parallelism in v9.6

- Parallel access methods
  - Seq scan is the only parallel access method
  - No support for parallel index, index-only or bitmap-heap scan
- Parallel joins
  - NestedLoop and Hash joins are supported for parallel execution
  - For hash-join, each worker prepares its own copy of hash-table
  - Merge join cannot execute in parallel
- Parallel aggregates
  - Each worker performs partial aggregate and finalize aggregate is done by leader

Performance evaluation on TPC-H

- Experimental setup
  - IBM power7 box (popularly known as Hydra in community)
- Parameter settings
  - Max_parallel_degree = 4
  - Work_mem = 64 MB
  - Shared_buffers = 8 GB
- Database setup
  - Scale factor = 10

Performance evaluation on TPC-H



Performance analysis: what's missing…?

- Need parallel-index scan
  - Q6, Q14
- Need parallel bitmap-heap scan
  - Q4, Q15
- Need parallel merge-join
  - Q2, Q3, Q9, Q20
- Need parallel hash table build
  - Q3, Q5, Q7, Q8, Q21
- Need parallel subquery handling
  - Q2, Q22

Limitations

- Many forbidden operations
  - Suspended queries e.g. cursors, etc.
  - No serializable isolation level
  - Many parallel unsafe functions
    - Statements changing transaction state
- Restricted operations
  - Scan nodes with InitPlan or Subplan or Subquery scan nodes cannot leverage parallelism
  - No parallelism for temporary tables, CTEs, foreign table scans
  - Parallel restricted functions

What to expect in coming versions

- More parallel executor nodes
  - `Access methods`
    - **Parallel index, index-only**, bitmap-heap
  - `Join methods`
    - Merge join
    - Hash join with shared hash
  - `Other`
    - Gather-merge
    - **Relaxation for nodes using uncorrelated sub-plan**, init-plan
    - Improvements in parallel-append
- Parallel DDL/maintenance commands
  - `Index-creation`
  - `Vacuum`

Upcoming v10: at a glance

- Parallel index scan
  - Firstly, a worker will process the intermediate pages of B-tree and determine the starting leaf page where scan is to be started
  - Next, all the workers start scanning the leaf pages block by block
  - Finally, all the filtered tuples are gathered by the leader process
- This operator improves the performance significantly when the database is in-memory
- Similar mechanism is built for index-only scans

Upcoming v 10: at a glance

- Parallel bitmap heap scan
  - A bitmap scan fetches all the pointers from index in one go, sort them using in-memory "bitmap", finally, visits the tuple in physical order
  - Bitmap will be created by a single worker
  - Next, all the workers will jointly scan the heap, page by page

  - For further improvement, we can also build bitmap by multiple workers

Upcoming v 10: at a glance

- Parallel bitmap heap scan

```
Gather
    Workers Planned: 2
    ->  Parallel Bitmap Heap Scan on foo
          Recheck Cond: ((a < 100000) OR (b <
10000))
          ->  BitmapOr
                ->  Bitmap Index Scan on idx1
                      Index Cond: (a < 100000)
                ->  Bitmap Index Scan on idx2
                      Index Cond: (b < 10000)
```

Upcoming v 10: at a glance

- Parallel Merge Join
  - If outer node is using parallelism then we consider parallel merge-join
    - Outer node will be scanned in parallel by multiple workers
    - Inner node will be processed completely by individual workers
  - There is still scope of improvements in this strategy
    - Parallelise inner sort or materialize nodes

Upcoming v 10: at a glance

- Parallel shared hash
  - Previously, each worker builds its own copy of hash table
  - This is particularly favourable to cases when hash table is small
  - Improved mechanism is to employ the workers for building hash-table in parallel
  - Once, hash-table is ready, parallel probing can be done
  - This facilitates the usage of parallel operators on either sides of joins

Upcoming v 10: at a glance

Parallel shared-hash

```
Gather
   Workers Planned: 2
   Workers Launched: 2
    -> Hash Join
         Hash Cond (foo.b = bar.b)
      -> Parallel Seq Scan on foo
      -> Parallel Shared Hash
         -> Parallel Seq Scan on bar
```

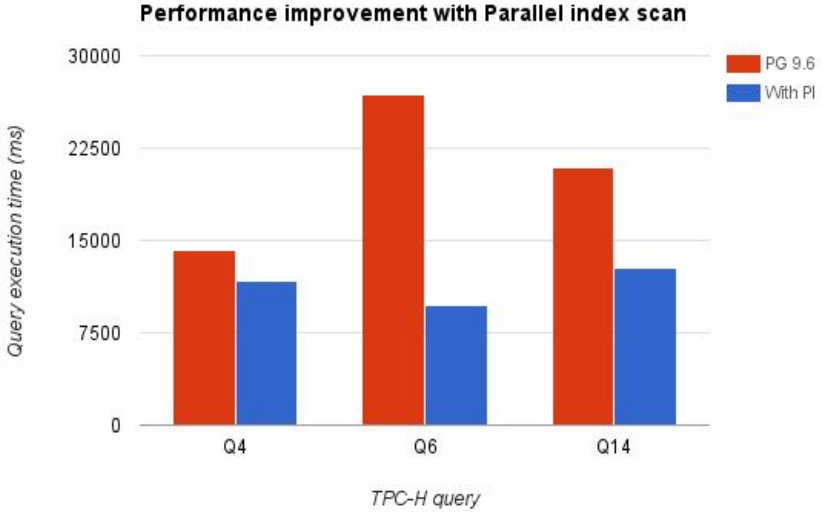
Upcoming v 10: at a glance

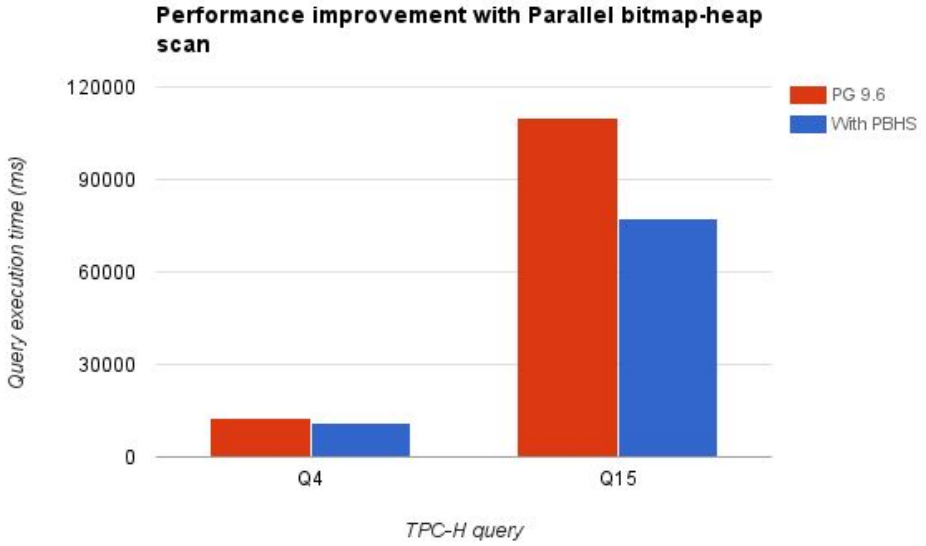
- Gather-merge
  - Previously, there was only one option to collect the result from parallel operators i.e gather, it does not maintain interesting order
  - Therefore, extra sort node is required on top for ordered output
  - Now, if workers are providing sorted result specifically, output from parallel index, parallel merge join, etc. then gather-merge will maintain the sort-order in the final result

Performance evaluation on TPC-H

- Experimental setup
  - RAM = 512 GB
  - Number of cores = 32
- Parameter settings
  - Work_mem = 64 MB
  - Shared_buffers = 8 GB
  - Effective_cache_size = 10 GB
  - Random_page_cost = seq_page_cost = 0.1
  - Max_parallel_workers_per_gather = 4
- Database setup
  - Scale factors = 20, 300
  - Additional indexes: l_shipmode, l_shipdate, o_orderdate, o_comment

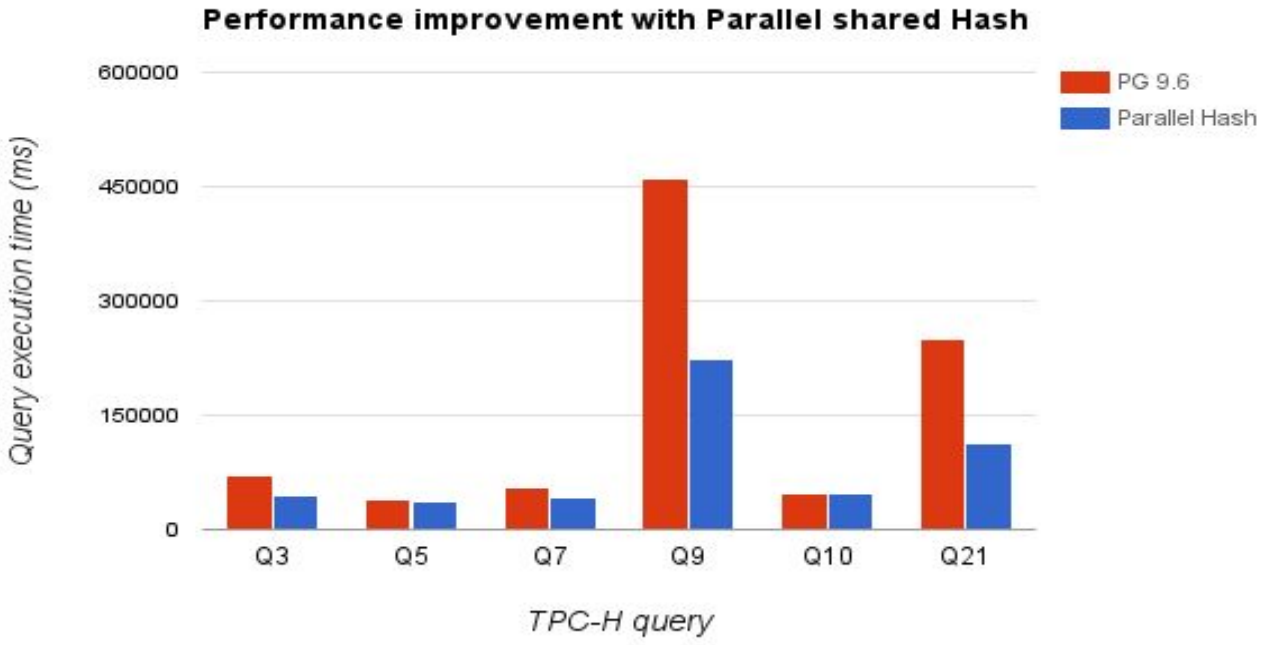
Performance evaluation on TPC-H





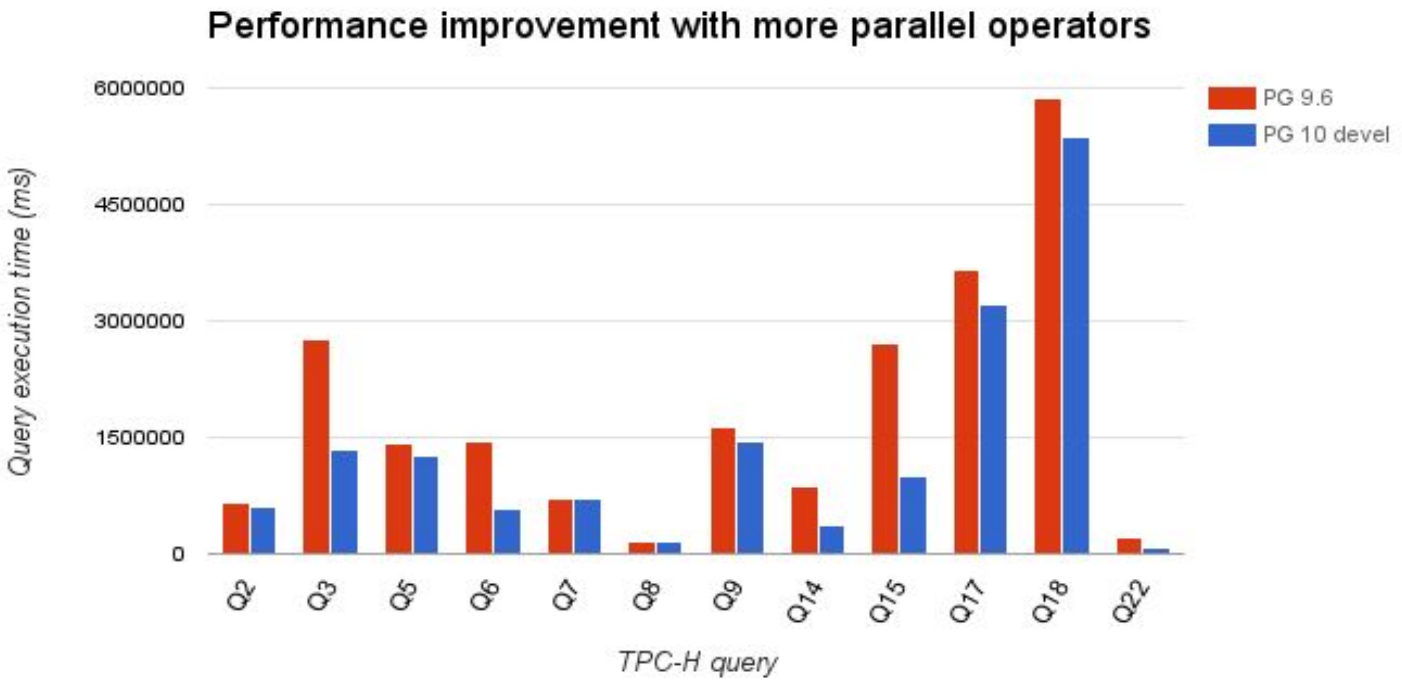
Results on scale factor 20

Performance evaluation on TPC-H



Results on scale factor 20

Performance evaluation on TPC-H



Results on scale factor 300

How to further improve performance

- Tuning parameters
  - Max_parallel_workers_per_gather
    - Recommended value 1 to 4
  - Reduce following costs
    - Parallel_tuple_cost: planner's estimate of the cost of transferring one tuple from a parallel worker process to another process
    - Parallel_setup_cost: planner's estimate for launching parallel workers and initializing dynamic shared memory
    - Min_parallel_table_scan_size: the minimum size of relations to be considered for parallel sequence scan
    - Min_parallel_index_scan_size: the minimum size of index to be considered for parallel scan
    - Random_page_cost: estimated cost of accessing a random page in disk
  - Increase following parameters
    - Work_mem
    - Effective_cache_size
    - Shared_buffers

Nightmares for parallel operators

- If the actual number of workers at execution time is less than planned number of workers
  - `Increase max_parallel_workers`
- Shared_buffer_size is lesser than the size of inner side of join
- Random_page_cost is set too low but database is not in memory
  - `Increase random_page_cost`
  - `Load data in memory`
- Drastic under-estimation in selectivities

Conclusion

- Adding intra-query parallelism improves per query response time
  - Previously, overall throughput was the only focus
  - This makes it more suitable for OLAP environments
- Till version 9.6, parallel support for sequence scan, hash join, nestloop join, and aggregates is available
  - Out of 22 queries of TPC-H, performance improved for 15 queries
  - In which 3 queries are at least 4 times faster and 11 queries are 2 times faster
- More parallel executor nodes are planned for upcoming versions
  - More parallel access methods - *index, index-only are already committed*
  - Improved parallel join mechanisms
  - Gather with interesting order
  - Removed restrictions for nodes using *SubPlans(already committed)* or InitPlans
  - Around 10 of 22 TPC-H queries show significant improvement in performance
  - In which around 4 queries show more than 2x improvement

Output: Thank You

```
Gather
    Workers Planned: 2
    Workers Launched: 2
    ->  Parallel Index Scan on Common_phrases
          Index Cond: ( value = 'Thank You' )
           Filter: Language = 'English'
```

Slide credits:
[1] https://www.pgcon.org/2016/schedule/events/913.en.html
[2] https://www.postgresql.eu/events/schedule/pgconfeu2016/session/1360-parallel-query-in-postgresql/