MODERNES VACUUM

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oapg-edu.org

VACUUM

- MVCC: Multi-Version Concurrency Control
- Update erzeugt neue Zeilen-Version
- alte Versionen müssen später aufgeräumt werden: VACUUM

```
=# select xmin, xmax, ctid, * from foo;
  xmin  | xmax |  ctid  | id |   t
--------+------+--------+----+-------
 476772 |    0 | (0,1)  |  1 | hello
 476772 |    0 | (0,3)  |  3 | hello
 476772 |    0 | (0,4)  |  4 | hello
```

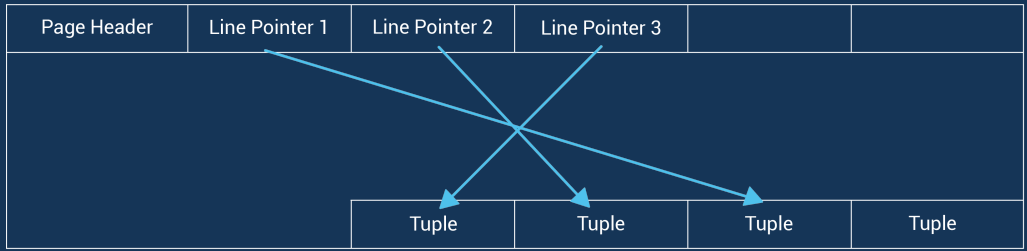

Einfaches VACUUM

- Tabelle scannen
- tote Tupel entfernen
  - xmin, xmax, Liste aktuell laufender Transaktionen
  - tot = xmax < txid_current and xmax has committed

```
=# create extension pageinspect;
=# select * from heap_page_items(get_raw_page('foo', 0));
 lp | lp_off | lp_flags | lp_len | t_xmin | t_xmax | t_field3 | t_ctid
----+--------+----------+--------+--------+--------+----------+--------
  1 |   8152 |        1 |     34 | 476772 |      0 |        0 | (0,1)
  2 |   8112 |        1 |     34 | 476772 | 476774 |        0 | (0,2)
  3 |   8072 |        1 |     34 | 476772 |      0 |        0 | (0,3)
  4 |   8032 |        1 |     34 | 476772 |      0 |        0 | (0,4)
  5 |      0 |        3 |      0 |    (n) |    (n) |      (n) | (n)
  6 |   7992 |        1 |     34 | 476772 |      0 |        0 | (0,6)
```


VACUUM mit Indexen

- Tabelle scannen
- tote Tupel mit LP_DEAD (3) markieren, ctid merken
- Indexe scannen, tote Einträge anhand ctid erkennen, löschen
- Tabelle nochmal scannen, tote Tupel entfernen



Speicherbedarf

- “ctid merken” = 6 Byte
- maintenance_work_mem (Default 64 MB)
- mehrere Index-Cleanup-Durchgänge

VACUUM mit Indexen und Memory-Limit

- Tabelle scannen
- loop:
  - tote Tupel mit LP_DEAD (3) markieren, ctid merken
  - Indexe scannen, tote Einträge anhand ctid erkennen, löschen
  - Tabelle nochmal scannen, tote Tupel entfernen
- VACUUM VERBOSE

Freezing

- xmin/xmax 32 Bit, Ringzähler -> 2^31 ~ 2 Mrd. Transaktionen
- alte Tupel müssen eingefroren werden
- alle Tabellen scannen und Tupel-Header umschreiben
- Teil von VACUUM

Modernes VACUUM

Wie können wir das verbessern?

- Autovacuum
- Geschwindigkeit
- Visibility Map
- Memory-Limits
- Parallelisierung
- Teile unabhängig laufen lassen

Rückblick

```
commit 6e6016cb0875aa0f46eff0919892379062c6964a
Author: mao <mao>
Date:   Sun May 5 19:46:07 1991 +0000

    'vacuum' is now a postquel command
```


7.4: pg_autovacuum

```
commit bd18c50ba87f12d1dc0aa65c1ff0507b2d1c5c41
Author:     Bruce Momjian <bruce@momjian.us>
AuthorDate: Thu Mar 20 18:14:46 2003 +0000

    I have updated my pg_autovacuum program (formerly pg_avd, the name
    changed as per discussion on the patches list).
    ...

    I have not tested the xid wraparound code as I have to let my AthlonXP
    1600 run select 1 in a tight loop for approx. two days in order to
    perform the required 500,000,000 xacts.

    Matthew T. O'Connor
```


8.0: Cost based vacuum delay feature

```
commit f425b605f4e97a4571372b116a1ec81daf88dfc8
Author:     Jan Wieck <JanWieck@Yahoo.com>
AuthorDate: Fri Feb 6 19:36:18 2004 +0000

    Cost based vacuum delay feature.

    Jan
```


8.1: Integrated autovacuum daemon

```
commit 29094193f526bf90671d71b59a2e007aad1fcae5
Author:     Tom Lane <tgl@sss.pgh.pa.us>
AuthorDate: Thu Jul 14 05:13:45 2005 +0000

    Integrate autovacuum functionality into the backend.  There's still a
    few loose ends to be dealt with, but it seems to work.  Alvaro Herrera,
    based on the contrib code by Matthew O'Connor.
```

- autovacuum_vacuum_scale_factor (default 0.4)

8.2: Make autovacuum behavior more aggressive

```
commit e0938c3f5b03e48bca32fe903f057e5777d43df8
Author:     Bruce Momjian <bruce@momjian.us>
AuthorDate: Sat Sep 2 23:12:16 2006 +0000

    Make autovacuum behavior more agressive, per discussion on hackers list
    --- was part of autovacuum default 'on' patch that was reverted, but we
    want this part.

    Peter Eisentraut
```

- autovacuum_vacuum_scale_factor (default 0.2)

8.3: Enable autovacuum in the default configuration

```
commit 10a5e3348eabc651fe89e93ec37bdbaefeba7a12
Author:     Álvaro Herrera <alvherre@alvh.no-ip.org>
AuthorDate: Tue Jan 16 18:26:02 2007 +0000

    Enable autovacuum in the default configuration, per discussion.

commit 53d2951be7687089885865f31949eda87439a80b
Author:     Álvaro Herrera <alvherre@alvh.no-ip.org>
AuthorDate: Tue Jul 24 01:53:56 2007 +0000

   Set a default autovacuum vacuum_cost_delay value of 20ms, to avoid excessive
    I/O utilization, per discussion.

   While at it, lower the autovacuum vacuum and analyze threshold values to 50
   tuples.  It is a bit higher (i.e. more conservative) than what I originally
    proposed but much better than the old values for small tables.
```

8.3: Add a multi-worker capability to autovacuum

```
commit e2a186b03cc1a87cf26644db18f28a20f10bd739
Author:     Álvaro Herrera <alvherre@alvh.no-ip.org>
AuthorDate: Mon Apr 16 18:30:04 2007 +0000

    Add a multi-worker capability to autovacuum.  This allows multiple worker
    processes to be running simultaneously.  Also, now autovacuum processes do not
    count towards the max_connections limit; they are counted separately from
     regular processes, and are limited by the new GUC variable
     autovacuum_max_workers.

    The launcher now has intelligence to launch workers on each database every
    autovacuum_naptime seconds, limited only on the max amount of worker slots
     available.

    Also, the global worker I/O utilization is limited by the vacuum cost-based
    delay feature.  Workers are "balanced" so that the total I/O consumption does
    not exceed the established limit.  This part of the patch was contributed by
```

8.3: Allow an autovacuum worker to be interrupted automatically

```
commit acac68b2bcae818bc8803b8cb8cbb17eee8d5e2b
Author:     Álvaro Herrera <alvherre@alvh.no-ip.org>
AuthorDate: Fri Oct 26 20:45:10 2007 +0000

    Allow an autovacuum worker to be interrupted automatically when it is found
    to be locking another process (except when it's working to prevent Xid
    wraparound problems).
```


Stand 8.3 (2008)

- Autovacuum
- Threshold = 20%
- 3 Worker
- Cost-based IO Limit
- 1 GB Memory pro Index-Durchgang

8.3: \h VACUUM

```
$ /usr/lib/postgresql/8.3/bin/psql
postgres=# \h VACUUM
Command:     VACUUM
Description: garbage-collect and optionally analyze a database
Syntax:
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] [ table ]
VACUUM [ FULL ] [ FREEZE ] [ VERBOSE ] ANALYZE [ table [ (column [, ...] ) ] ]
```


18: \h VACUUM

```
postgres=# \h VACUUM
VACUUM [ ( Option [, ...] ) ] [ Tabelle-und-Spalten [, ...] ]
    FULL [ boolean ]
    FREEZE [ boolean ]
    VERBOSE [ boolean ]
    ANALYZE [ boolean ]
    DISABLE_PAGE_SKIPPING [ boolean ]
    SKIP_LOCKED [ boolean ]
    INDEX_CLEANUP { AUTO | ON | OFF }
    PROCESS_MAIN [ boolean ]
    PROCESS_TOAST [ boolean ]
    TRUNCATE [ boolean ]
    PARALLEL ganze_Zahl
    SKIP_DATABASE_STATS [ boolean ]
    ONLY_DATABASE_STATS [ boolean ]
    BUFFER_USAGE_LIMIT Größe
```

https://www.postgresql.org/about/featurematrix/#vacuum-and-maintenance

VACUUM and Maintenance

	17	16	15	14	13	12	11	10	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.4	8.3	8.2	8.1
Inserted data can trigger autovacuum	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Integrated autovacuum daemon	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Page freezing optimizations	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Parallelized VACUUM for Indexes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Parallel vacuumdb jobs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
Radix tree memory structure for vacuum	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Vacuum "emergency mode"	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
Visibility Map for Vacuuming	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

Zeitleiste

- 8.4: Visibility Map for Vacuuming
- 9.4: New autovacuum_work_mem parameter
- 9.5: Parallel vacuumdb jobs (`vacuumdb --jobs`)
- 9.6: Don’t vacuum all-frozen pages
- 9.6: Add VACUUM (DISABLE_PAGE_SKIPPING) for emergencies
- 12: Add option SKIP_LOCKED to VACUUM and ANALYZE
- 12: Reduce default value of autovacuum_vacuum_cost_delay to 2ms
- 12: Allow VACUUM to be run with index cleanup disabled
- 12: Add TRUNCATE parameter to VACUUM

Zeitleiste

- 13: Parallelized VACUUM for Indexes (`vacuumdb --parallel`)
- 13: Inserted data can trigger autovacuum
- 14: Add option PROCESS_TOAST to VACUUM
- 14: Vacuum “emergency mode”
- 14: Teach VACUUM to bypass unnecessary index vacuuming
- 15: Default to log_checkpoints=on, log_autovacuum_min_duration=10m
- 16: Page freezing optimizations
- 16: Add VACUUM/ANALYZE BUFFER_USAGE_LIMIT option
- 17: Radix tree memory structure for vacuum
- 18: Allow changing autovacuum_max_workers without restarting
- 18: Track per-relation cumulative time spent in [auto]vacuum and [auto]analyze
- 18: Introduce autovacuum_vacuum_max_threshold

8.4: Visibility Map for Vacuuming

```
commit 608195a3a3656145a7eec7a47d903bc684011d73
Author:     Heikki Linnakangas <heikki.linnakangas@iki.fi>
AuthorDate: Wed Dec 3 13:05:22 2008 +0000

    Introduce visibility map. The visibility map is a bitmap with one bit per
    heap page, where a set bit indicates that all tuples on the page are
    visible to all transactions, and the page therefore doesn't need
    vacuuming. It is stored in a new relation fork.

    Lazy vacuum uses the visibility map to skip pages that don't need
    vacuuming. Vacuum is also responsible for setting the bits in the map.
    In the future, this can hopefully be used to implement index-only-scans,
    but we can't currently guarantee that the visibility map is always 100%
    up-to-date.
```


9.4: New autovacuum_work_mem parameter

```
commit 8693559cacf1765697c32fc38574af3c19ce61c1
Author: Simon Riggs <simon@2ndQuadrant.com>
Date:   Thu Dec 12 11:42:39 2013 +0000

    New autovacuum_work_mem parameter

    If autovacuum_work_mem is set, autovacuum workers now use
    this parameter in preference to maintenance_work_mem.

    Peter Geoghegan
```


9.5: Parallel vacuumdb jobs (`vacuumdb --jobs`)

```
commit a17923204736d8842eade3517d6a8ee81290fca4
Author:     Álvaro Herrera <alvherre@alvh.no-ip.org>
AuthorDate: Fri Jan 23 15:02:45 2015 -0300

    vacuumdb: enable parallel mode

    This mode allows vacuumdb to open several server connections to vacuum
    or analyze several tables simultaneously.

    Author: Dilip Kumar.  Some reworking by Álvaro Herrera
    Reviewed by: Jeff Janes, Amit Kapila, Magnus Hagander, Andres Freund
```

- VACUUM macht immer nur eine Tabelle gleichzeitig

9.6: Don’t vacuum all-frozen pages

```
commit fd31cd265138019dcccc9b5fe53043670898bc9f
Author:     Robert Haas <rhaas@postgresql.org>
AuthorDate: Thu Mar 10 16:12:10 2016 -0500

    Don't vacuum all-frozen pages.

    This should greatly reduce the cost of anti-wraparound vacuuming
    on large clusters where the majority of data is never touched
    between one cycle and the next, because we'll no longer have to
    read all of those pages only to find out that we don't need to
    do anything with them.

    Patch by me, reviewed by Masahiko Sawada.
```


9.6: Add VACUUM (DISABLE_PAGE_SKIPPING) for emergencies

```
commit ede62e56fbe809baa1a7bc3873d82f12ffe7540b
Author: Robert Haas <rhaas@postgresql.org>
Date:   Fri Jun 17 15:48:57 2016 -0400

    Add VACUUM (DISABLE_PAGE_SKIPPING) for emergencies.

    If you really want to vacuum every single page in the relation,
    regardless of apparent visibility status or anything else, you can use
    this option.  In previous releases, this behavior could be achieved
    using VACUUM (FREEZE), but because we can now recognize all-frozen
    pages as not needing to be frozen again, that no longer works.  There
    should be no need for routine use of this option, but maybe bugs or
    disaster recovery will necessitate its use.

    Patch by me, reviewed by Andres Freund.
```


12: Add option SKIP_LOCKED to VACUUM and ANALYZE

```
commit 803b1301e8c9aac478abeec62824a5d09664ffff
Author: Michael Paquier <michael@paquier.xyz>
Date:   Thu Oct 4 09:00:33 2018 +0900

    Add option SKIP_LOCKED to VACUUM and ANALYZE

    When specified, this option allows VACUUM to skip the work on a relation
    if there is a conflicting lock on it when trying to open it at the
    beginning of its processing.

    Similarly to autovacuum, this comes with a couple of limitations while
    the relation is processed which can cause the process to still block:
    ...

    Author: Nathan Bossart
    Reviewed-by: Michael Paquier, Andres Freund, Masahiko Sawada
```

12: Reduce default value of autovacuum_vacuum_cost_delay to 2ms

```
commit cbccac371c79d96c44fcd8c9cbb5ff4dedaaa522
Author: Tom Lane <tgl@sss.pgh.pa.us>
Date:   Sun Mar 10 15:16:21 2019 -0400

    Reduce the default value of autovacuum_vacuum_cost_delay to 2ms.

    This is a better way to implement the desired change of increasing
    autovacuum's default resource consumption.

    Discussion: https://postgr.es/m/28720.1552101086@sss.pgh.pa.us
```


12: Allow VACUUM to be run with index cleanup disabled

```
commit a96c41feec6b6616eb9d5baee9a9e08c20533c38
Author: Robert Haas <rhaas@postgresql.org>
Date:   Thu Apr 4 14:58:53 2019 -0400

    Allow VACUUM to be run with index cleanup disabled.

    This commit adds a new reloption, vacuum_index_cleanup, which
    controls whether index cleanup is performed for a particular
    relation by default.  It also adds a new option to the VACUUM
    command, INDEX_CLEANUP, which can be used to override the
    reloption.  If neither the reloption nor the VACUUM option is
    used, the default is true, as before.

    Masahiko Sawada, reviewed and tested by Nathan Bossart, Alvaro
    Herrera, Kyotaro Horiguchi, Darafei Praliaskouski, and me.
    The wording of the documentation is mostly due to me.
```


12: Add TRUNCATE parameter to VACUUM

```
commit b84dbc8eb80b43e554891c459a19969d9fbdefe5
Author: Fujii Masao <fujii@postgresql.org>
Date:   Wed May 8 02:10:33 2019 +0900

    Add TRUNCATE parameter to VACUUM.

    This commit adds new parameter to VACUUM command, TRUNCATE,
    which specifies that VACUUM should attempt to truncate off
    any empty pages at the end of the table and allow the disk space
    for the truncated pages to be returned to the operating system.

    This parameter, if specified, overrides the vacuum_truncate
    reloption. If neither the reloption nor the VACUUM option is
    used, the default is true, as before.

    Author: Fujii Masao
    Reviewed-by: Julien Rouhaud, Masahiko Sawada
```


13: Parallelized VACUUM for Indexes (`vacuumdb --parallel`)

```
commit 40d964ec997f64227bc0ff5e058dc4a5770a70a9
Author:     Amit Kapila <akapila@postgresql.org>
AuthorDate: Mon Jan 20 07:57:49 2020 +0530

    Allow vacuum command to process indexes in parallel.

    This feature allows the vacuum to leverage multiple CPUs in order to
    process indexes.  This enables us to perform index vacuuming and index
    cleanup with background workers.  This adds a PARALLEL option to VACUUM
    command where the user can specify the number of workers that can be used
    to perform the command which is limited by the number of indexes on a
    table.  Specifying zero as a number of workers will disable parallelism.
    This option can't be used with the FULL option.

    Author: Masahiko Sawada and Amit Kapila
    Reviewed-by: Dilip Kumar, Amit Kapila, Robert Haas, Tomas Vondra,
    Mahendra Singh and Sergei Kornilov
```


13: Inserted data can trigger autovacuum

```
commit b07642dbcd8d5de05f0ee1dbb72dd6760dd30436
Author:     David Rowley <drowley@postgresql.org>
AuthorDate: Sat Mar 28 19:20:12 2020 +1300

    Trigger autovacuum based on number of INSERTs

    Traditionally autovacuum has only ever invoked a worker based on the
    estimated number of dead tuples in a table and for anti-wraparound
    purposes. For the latter, with certain classes of tables such as
    insert-only tables, anti-wraparound vacuums could be the first vacuum that
    the table ever receives. This could often lead to autovacuum workers being
    busy for extended periods of time due to having to potentially freeze
    every page in the table. This could be particularly bad for very large
    tables. New clusters, or recently pg_restored clusters could suffer even
    ...
```


13: Inserted data can trigger autovacuum

```
    ...
There are additional benefits to triggering autovacuums based on inserts,
as tables which never contain enough dead tuples to trigger an autovacuum
are now more likely to receive a vacuum, which can mark more of the table
as "allvisible" and encourage the query planner to make use of Index Only
 Scans.

 Author: Laurenz Albe, Darafei Praliaskouski
Reviewed-by: Alvaro Herrera, Masahiko Sawada, Chris Travers, Andres Freund, Jus
Discussion: https://postgr.es/m/CAC8Q8t%2Bj36G_bLF%3D%2B0iMo6jGNWnLnWb1tujXu
```


14: Add option PROCESS_TOAST to VACUUM

```
commit 7cb3048f38e26b39dd5fd412ed8a4981b6809b35
Author: Michael Paquier <michael@paquier.xyz>
Date:   Tue Feb 9 14:13:57 2021 +0900

    Add option PROCESS_TOAST to VACUUM

    This option controls if toast tables associated with a relation are
    vacuumed or not when running a manual VACUUM.  It was already possible
    to trigger a manual VACUUM on a toast relation without processing its
    main relation, but a manual vacuum on a main relation always forced a
    vacuum on its toast table.  This is useful in scenarios where the level
    of bloat or transaction age of the main and toast relations differs a
    lot.

    A new option switch, called --no-process-toast, is added to vacuumdb.

    Author: Nathan Bossart
```


14: Vacuum “emergency mode”

```
commit 1e55e7d1755cefbb44982fbacc7da461fa8684e6
Author: Peter Geoghegan <pg@bowt.ie>
Date:   Wed Apr 7 12:37:45 2021 -0700

    Add wraparound failsafe to VACUUM.

    Add a failsafe mechanism that is triggered by VACUUM when it notices
    that the table's relfrozenxid and/or relminmxid are dangerously far in
    the past.  VACUUM checks the age of the table dynamically, at regular
    intervals.

    Author: Masahiko Sawada <sawada.mshk@gmail.com>
    Author: Peter Geoghegan <pg@bowt.ie>
```

- no indexes, no vacuuming, no speed limit
- vacuum_failsafe_age = 1,6 Mrd

14: Teach VACUUM to bypass unnecessary index vacuuming

```
commit 5100010ee4d5c8ef46619dbd1d17090c627e6d0a
Author: Peter Geoghegan <pg@bowt.ie>
Date:   Wed Apr 7 16:14:54 2021 -0700

    Teach VACUUM to bypass unnecessary index vacuuming.
    ...

    We only skip index vacuuming when 2% or less of the table's pages have
    one or more LP_DEAD items -- bypassing index vacuuming as an
    optimization must not noticeably impede setting bits in the visibility
    map.

    Author: Masahiko Sawada <sawada.mshk@gmail.com>
    Author: Peter Geoghegan <pg@bowt.ie>
```

- Blogpost kommt: https://www.cybertec-postgresql.com/en/blog/

15: Default log_checkpoints=on, log_autovacuum_min_duration=10m

```
commit 64da07c41a8c0a680460cdafc79093736332b6cf
Author:     Robert Haas <rhaas@postgresql.org>
AuthorDate: Mon Dec 13 09:48:04 2021 -0500

    Default to log_checkpoints=on, log_autovacuum_min_duration=10m

    The idea here is that when a performance problem is known to have
    occurred at a certain point in time, it's a good thing if there is
    some information available from the logs to help figure out what
    might have happened around that time.

    Bharath Rupireddy, reviewed by Fujii Masao and by me. Many other
    people commented on the thread, but as far as I can see that was
    discussion of the merits of the change rather than review of the
    patch.

    Discussion: https://postgr.es/m/CALj2ACX-fW_0eUDcp4qrFUAkf1f50Fnh138dmkd0Jkv
```


16: Page freezing optimizations

```
commit c3ffa731a5f99c4361203015ce2219d209fea94c
Author: Peter Geoghegan <pg@bowt.ie>
Date:   Wed Aug 31 11:37:35 2022 -0700

    Derive freeze cutoff from nextXID, not OldestXmin.

commit 9e5405993c1e242ae6fb7561353e437241244ac1
Author: Peter Geoghegan <pg@bowt.ie>
Date:   Tue Nov 15 07:48:41 2022 -0800

    Deduplicate freeze plans in freeze WAL records.

commit 1de58df4fec7325d91f5a8345757314be7ac05da
Author: Peter Geoghegan <pg@bowt.ie>
Date:   Wed Dec 28 08:50:47 2022 -0800

    Add page-level freezing to VACUUM.
```


16: SKIP_DATABASE_STATS and ONLY_DATABASE_STATS

```
commit a46a7011b27188af526047a111969f257aaf4db8
Author: Tom Lane <tgl@sss.pgh.pa.us>
Date:   Fri Jan 6 14:17:25 2023 -0500

    Add options to control whether VACUUM runs vac_update_datfrozenxid.

    VACUUM normally ends by running vac_update_datfrozenxid(), which
    requires a scan of pg_class.  Therefore, if one attempts to vacuum a
    database one table at a time --- as vacuumdb has done since v12 ---
    we will spend O(N^2) time in vac_update_datfrozenxid().  That causes
    serious performance problems in databases with tens of thousands of
    tables, and indeed the effect is measurable with only a few hundred.
    To add insult to injury, only one process can run
    vac_update_datfrozenxid at the same time per DB, so this behavior
    largely defeats vacuumdb's -j option.

    Tom Lane and Nathan Bossart
```


16: Add PROCESS_MAIN to VACUUM

```
commit 4211fbd8413b26e0abedbe4338aa7cda2cd469b4
Author: Michael Paquier <michael@paquier.xyz>
Date:   Mon Mar 6 16:41:05 2023 +0900

    Add PROCESS_MAIN to VACUUM

    Disabling this option is useful to run VACUUM (with or without FULL) on
    only the toast table of a relation, bypassing the main relation.  This
    option is enabled by default.

    So this feature is basically a shortcut to be able to run VACUUM or VACUUM
    FULL on a toast relation, using only the name of the parent relation.

    Author: Nathan Bossart
```


16: Add VACUUM/ANALYZE BUFFER_USAGE_LIMIT option

```
commit 1cbbee03385763b066ae3961fc61f2cd01a0d0d7
Author: David Rowley <drowley@postgresql.org>
Date:   Fri Apr 7 11:40:31 2023 +1200

    Add VACUUM/ANALYZE BUFFER_USAGE_LIMIT option

    Add new options to the VACUUM and ANALYZE commands called
    BUFFER_USAGE_LIMIT to allow users more control over how large to make the
    buffer access strategy that is used to limit the usage of buffers in
    shared buffers.  Larger rings can allow VACUUM to run more quickly but
    have the drawback of VACUUM possibly evicting more buffers from shared
    buffers that might be useful for other queries running on the database.

    Per idea by Andres Freund.

    Author: Melanie Plageman
```


17: Radix tree memory structure for vacuum

```
commit 667e65aac354975c6f8090c6146fceb8d7b762d6
Author: Masahiko Sawada <msawada@postgresql.org>
Date:   Tue Apr 2 10:15:37 2024 +0900

    Use TidStore for dead tuple TIDs storage during lazy vacuum.

    Since the backing radix tree makes small allocations as needed, the
    1GB limit is now gone. Further, the total memory used is now often
    smaller by an order of magnitude or more, depending on the
    distribution of blocks and offsets. These two features should make
    multiple rounds of heap scanning and index cleanup an extremely rare
    event. TID lookup during index cleanup is also several times faster,
    even more so when index order is correlated with heap tuple order.

    Reviewed-by: John Naylor, (in an earlier version) Dilip Kumar
```


18: Allow changing autovacuum_max_workers without restarting

```
commit c758119e5bfb47b38cf957f9a5a37ceae96fa9b3
Author:     Nathan Bossart <nathan@postgresql.org>
AuthorDate: Mon Jan 6 15:01:22 2025 -0600

    Allow changing autovacuum_max_workers without restarting.

    This commit introduces a new parameter named
    autovacuum_worker_slots that controls how many autovacuum worker
    slots to reserve during server startup.  Modifying this new
    parameter's value does require a server restart, but it should
    typically be set to the upper bound of what you might realistically
    need to set autovacuum_max_workers.  With that new parameter in
    place, autovacuum_max_workers can now be changed with a SIGHUP
    (e.g., pg_ctl reload).

    Reviewed-by: Sami Imseih, Justin Pryzby, Robert Haas, Andres Freund, Yogesh Sha
    Discussion: https://postgr.es/m/20240410212544.GA1824549%40nathanxps13
```

18: Track time spent in [auto]vacuum and [auto]analyze

```
commit 30a6ed0ce4bb18212ec38cdb537ea4b43bc99b83
Author: Michael Paquier <michael@paquier.xyz>
Date:   Tue Jan 28 09:57:32 2025 +0900

    Track per-relation cumulative time spent in [auto]vacuum and [auto]analyze

    This commit adds four fields to the statistics of relations, aggregating
    the amount of time spent for each operation on a relation:
    - total_vacuum_time, for manual vacuum.
    - total_autovacuum_time, for vacuum done by the autovacuum daemon.
    - total_analyze_time, for manual analyze.
    - total_autoanalyze_time, for analyze done by the autovacuum daemon.

    Author: Sami Imseih
    Reviewed-by: Bertrand Drouvot, Michael Paquier
    Discussion: https://postgr.es/m/CAA5RZ0uVOGBYmPEeGF2d1B_67tgNjKx_bKDuL+tvftu
```


18: Introduce autovacuum_vacuum_max_threshold

```
commit 306dc520b9dfd6014613961962a89940a431a069
Author:     Nathan Bossart <nathan@postgresql.org>
AuthorDate: Wed Feb 5 15:48:18 2025 -0600

    Introduce autovacuum_vacuum_max_threshold.

    This new parameter provides a way to set a limit on the value
    calculated with autovacuum_vacuum_threshold and
    autovacuum_vacuum_scale_factor so that very large tables are
    vacuumed more frequently.  By default, it is set to 100,000,000
    tuples, but it can be disabled by setting it to -1.  It can also be
    adjusted for individual tables by changing storage parameters.

    Author: Nathan Bossart <nathandbossart@gmail.com>
    Co-authored-by: Frédéric Yhuel <frederic.yhuel@dalibo.com>
```

18: \h VACUUM

```
postgres=# \h VACUUM
VACUUM [ ( Option [, ...] ) ] [ Tabelle-und-Spalten [, ...] ]
    FULL [ boolean ]
    FREEZE [ boolean ]
    VERBOSE [ boolean ]
    ANALYZE [ boolean ]
    DISABLE_PAGE_SKIPPING [ boolean ]
    SKIP_LOCKED [ boolean ]
    INDEX_CLEANUP { AUTO | ON | OFF }
    PROCESS_MAIN [ boolean ]
    PROCESS_TOAST [ boolean ]
    TRUNCATE [ boolean ]
    PARALLEL ganze_Zahl
    SKIP_DATABASE_STATS [ boolean ]
    ONLY_DATABASE_STATS [ boolean ]
    BUFFER_USAGE_LIMIT Größe
```

postgres=# \dconfig *vacuum*

Liste der Konfigurationsparameter

Parameter	Wert	Parameter	Wert
autovacuum	on	log_autovacuum_min_duration	10min
autovacuum_analyze_scale_factor	0.1	vacuum_buffer_usage_limit	2MB
autovacuum_analyze_threshold	50	vacuum_cost_delay	0
autovacuum_freeze_max_age	200000000	vacuum_cost_limit	200
autovacuum_max_workers	3	vacuum_cost_page_dirty	20
autovacuum_multixact_freeze_max_age	400000000	vacuum_cost_page_hit	1
autovacuum_naptime	1min	vacuum_cost_page_miss	2
autovacuum_vacuum_cost_delay	2ms	vacuum_failsafe_age	1600000000
autovacuum_vacuum_cost_limit	-1	vacuum_freeze_min_age	50000000
autovacuum_vacuum_insert_scale_factor	0.2	vacuum_freeze_table_age	150000000
autovacuum_vacuum_insert_threshold	1000	vacuum_max_eager_freeze_failure_rate	0.03
autovacuum_vacuum_max_threshold	100000000	vacuum_multixact_failsafe_age	1600000000
autovacuum_vacuum_scale_factor	0.2	vacuum_multixact_freeze_min_age	5000000
autovacuum_vacuum_threshold	50	vacuum_multixact_freeze_table_age	150000000
autovacuum_worker_slots	16	vacuum_truncate	on
autovacuum_work_mem	-1		

(31 Zeilen)

Defaults

- Alles in allem okay, viel mehr Performance
- Vacuum cost limit (12: `autovacuum_vacuum_cost_delay=2ms`)
- Freezing weniger furchterregend (9.6: VM, 14: emergency, 16: page freezing)
  - trotzdem pg_database.datfrozenxid beobachten
- `autovacuum_max_workers=3` ist wenig
- `autovacuum_vacuum_scale_factor=0.2`
  - Lösung autovacuum_vacuum_max_threshold?
- Automatischer Index-Skip (2%) ist überraschend (14)
- `alter table foo set ( vacuum_truncate = off );`