Table Repacking, done right

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- Postgres contributor since 2002
- Working as a Postgres developer for EDB since 2012

Talk structure

1. The problem: table bloat
2. The historical solution: VACUUM and friends
3. Third-party solutions
   - `pg_reorg`
   - `pg_repack`
   - `pg_squeeze`
4. Non-concurrent `REPACK`
5. `REPACK (CONCURRENTLY)`

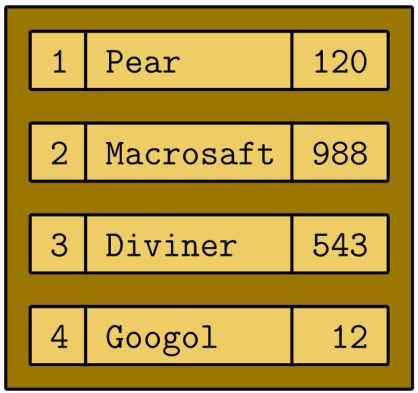
Table bloat

- Comes from *non-overwriting* MVCC implementation
- Non-overwriting: old versions of updated tuples are not immediately removable
- *vacuuming*[1] takes care of them afterwards

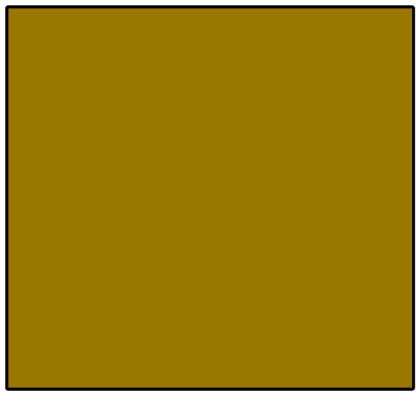
[1] And HOT-pruning.

Table bloat: other databases

table: companies

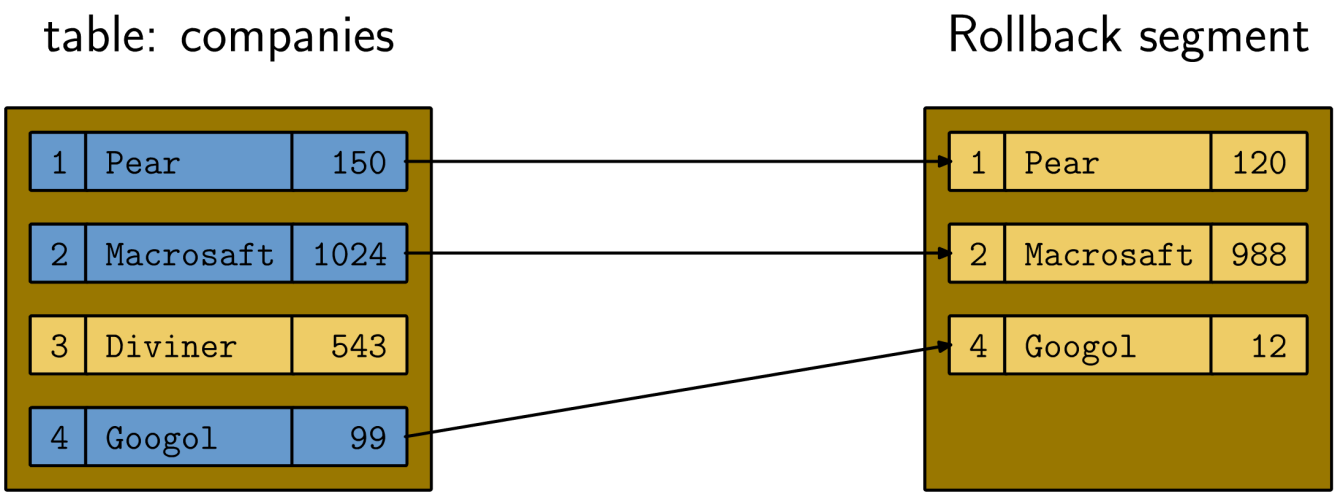


Rollback segment



An overwriting storage manager might use a “rollback segment”

Table bloat: other databases



As the table is updated, old tuples versions are moved to the rollback segment. The table doesn't need later cleanup.

A rollback segment?

- requires handling of disk space for it
- and later cleanup
- notably: rollbacks are expensive
- and is more difficult to implement
- Postgres tried: see `zheap`
- Not yet achieved!

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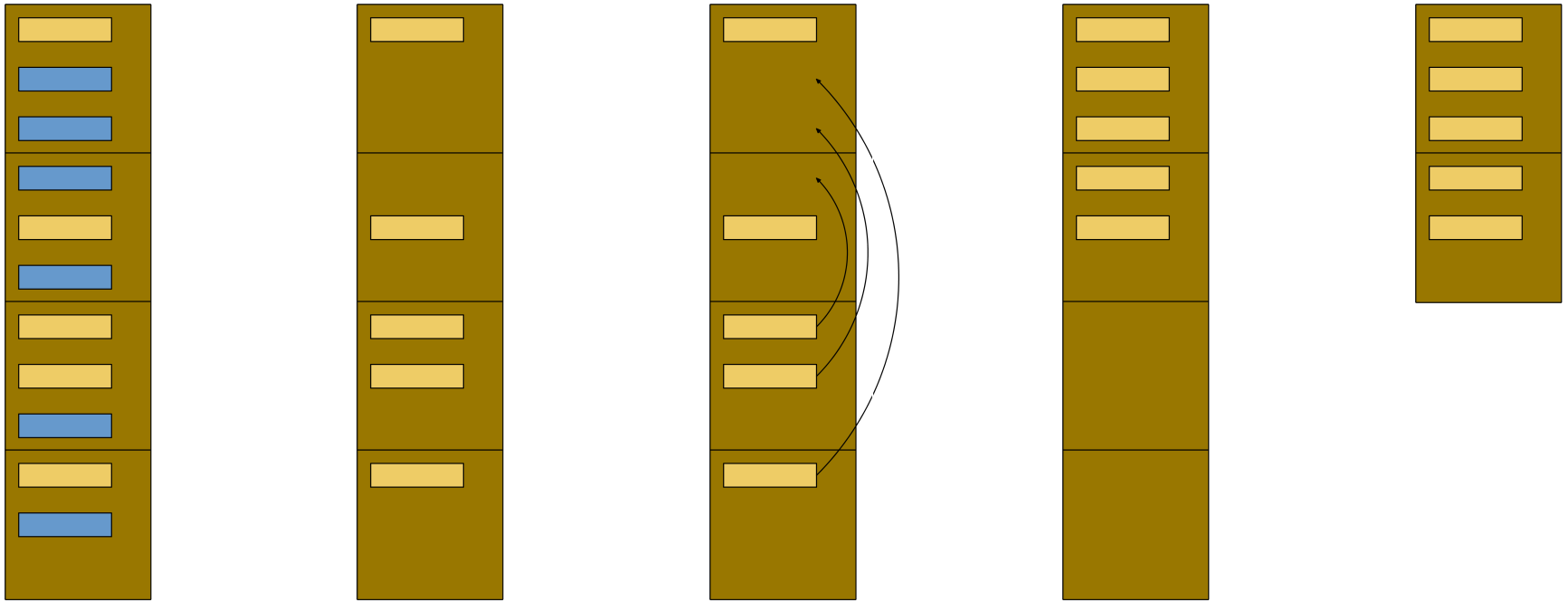
Berkeley: Ancient vacuuming technique



some dead tuples

dead tuples are removed

tuples moved to final locations

tuples in final locations

table can be truncated

“Lazy” vacuum?

- But this required “access exclusive” lock on the table
- Commit 4046e58c2478:
  Initial implementation of concurrent VACUUM.
  Tom Lane

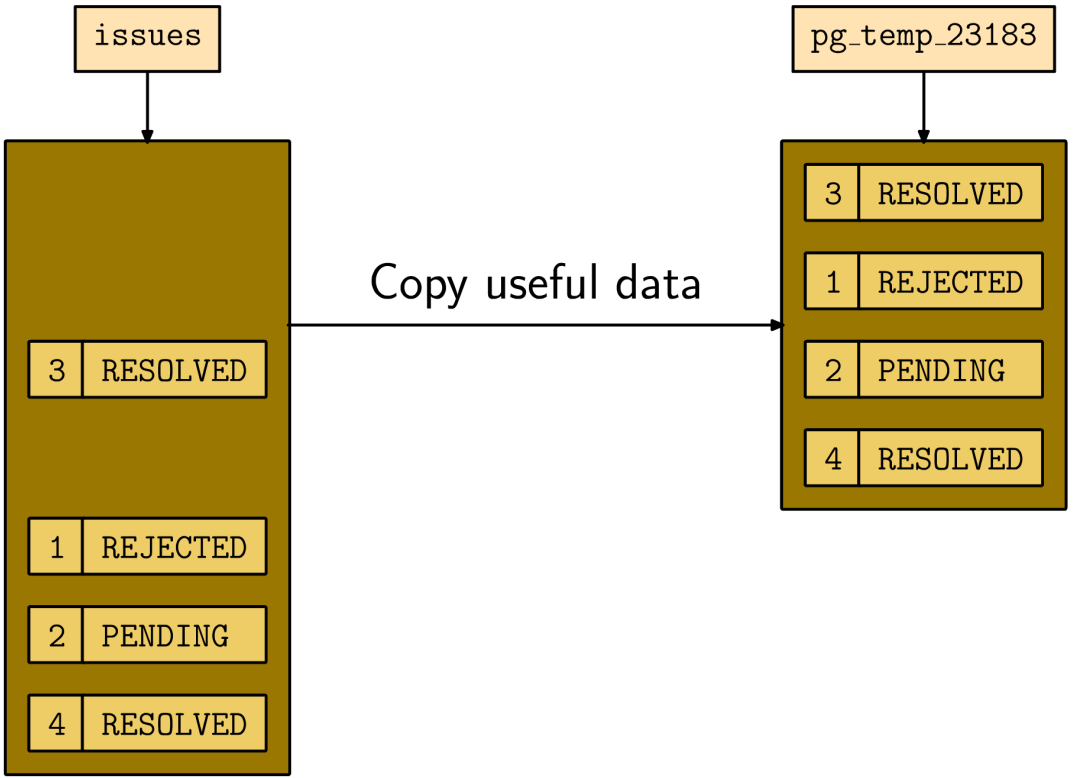
  Fri Jul 13 2001, Postgres 7.2
- Doesn’t require access exclusive lock anymore
- Operation can continue
- Disadvantage: surviving tuples cannot be moved across pages
- Old-style vacuum is renamed `VACUUM FULL`

A faster VACUUM FULL?

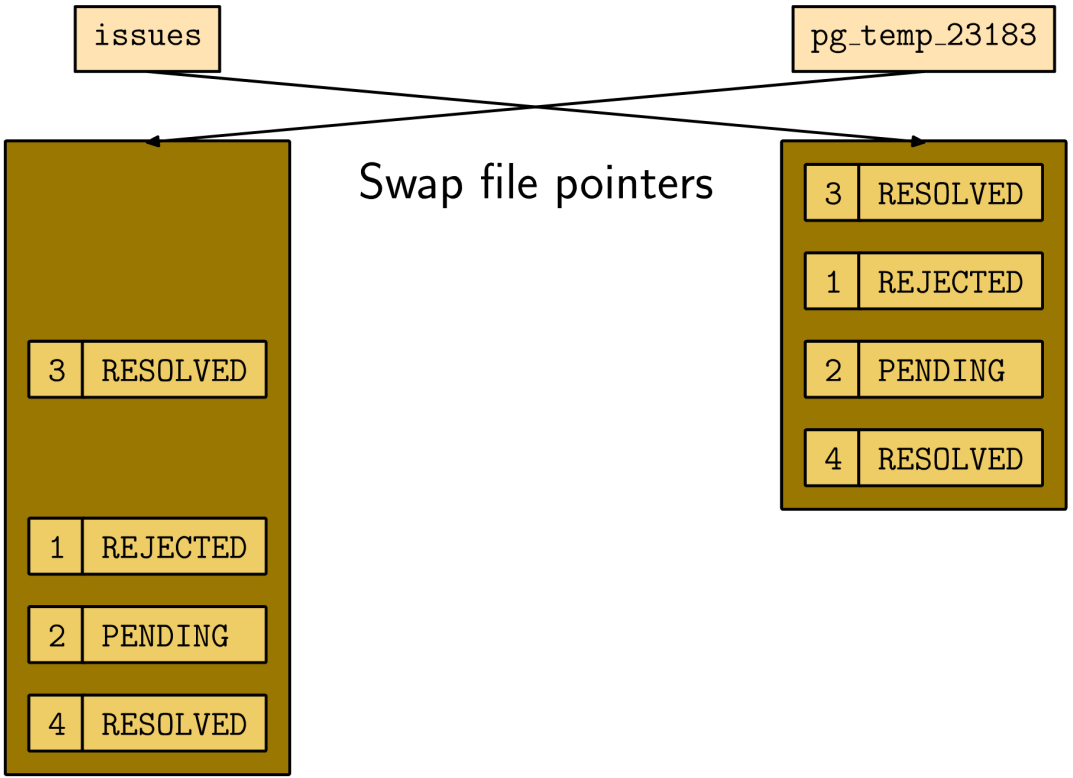
- Yes! *"Let's use `CLUSTER`," someone said*
- In 2010 (Postgres 9.0), VACUUM FULL was changed to use the CLUSTER code
- Commit 946cf229e89f:
  Support rewritten-based full vacuum as VACUUM FULL. Traditional VACUUM FULL was renamed to VACUUM FULL INPLACE.
  Itagaki Takahiro

  Wed Jan 6 2010, Postgres 9.0
- Original renamed `VACUUM FULL INPLACE`
- How does this work?

CLUSTER-based VACUUM FULL



CLUSTER-based VACUUM FULL



VACUUM FULL INPLACE removed

- Commit 0a469c87692d:
  Remove old-style VACUUM FULL (which was known for a little while as VACUUM FULL INPLACE), along with a boatload of subsidiary code and complexity. Per discussion, the use case for this method of vacuuming is no longer large enough to justify maintaining it; not to mention that we don't wish to invest the work that would be needed to make it play nicely with Hot Standby.
  Tom Lane

  Mon Feb 8 2010, Postgres 9.0

pg_reorg

- Created in 2008 by NTT
- https://ossc-db.github.io/pg_reorg/

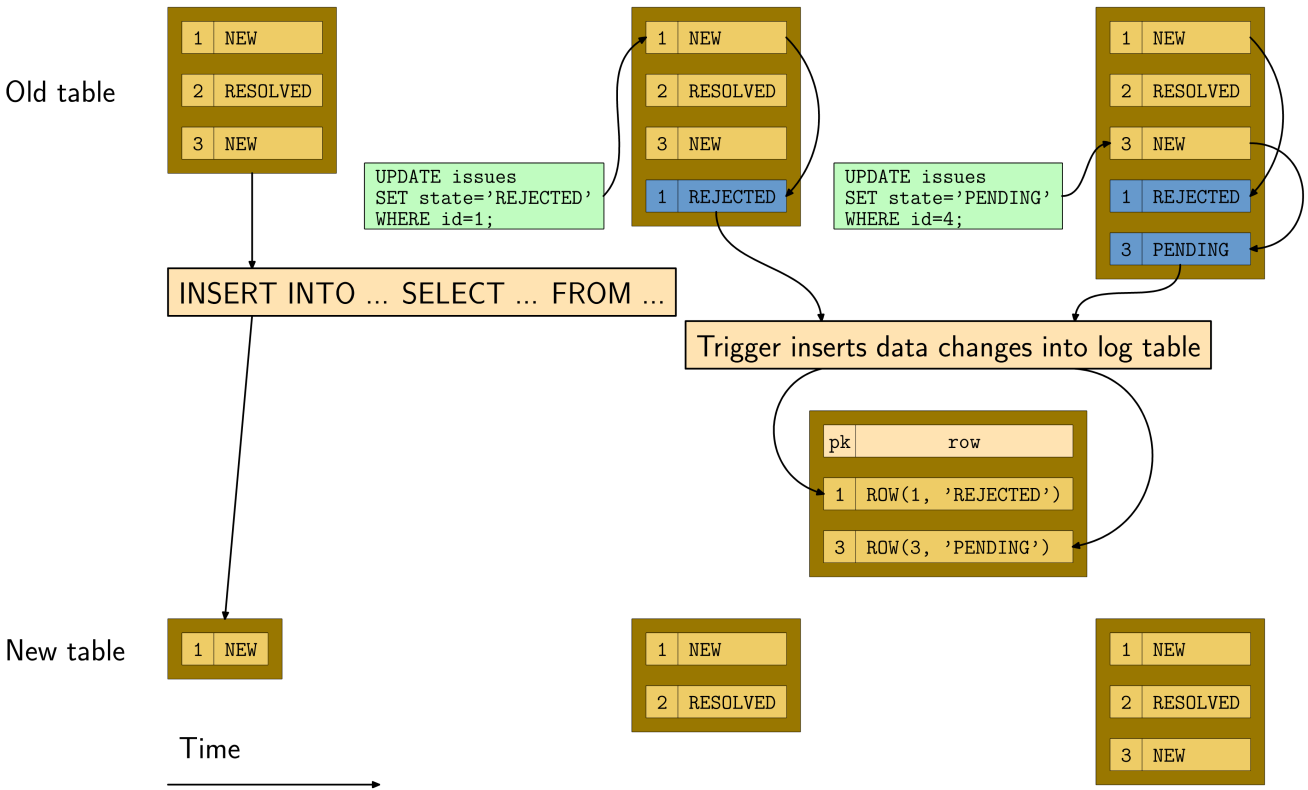
  "The module is developed to be a better alternative of CLUSTER and VACUUM FULL."
- Featured in Depesz's blog in 2011: Bloat Happens

  "All in all – it's a great tool, which does amazing job."
- Last release was 1.1.9 in 2013
- Pronounced dead in 2020

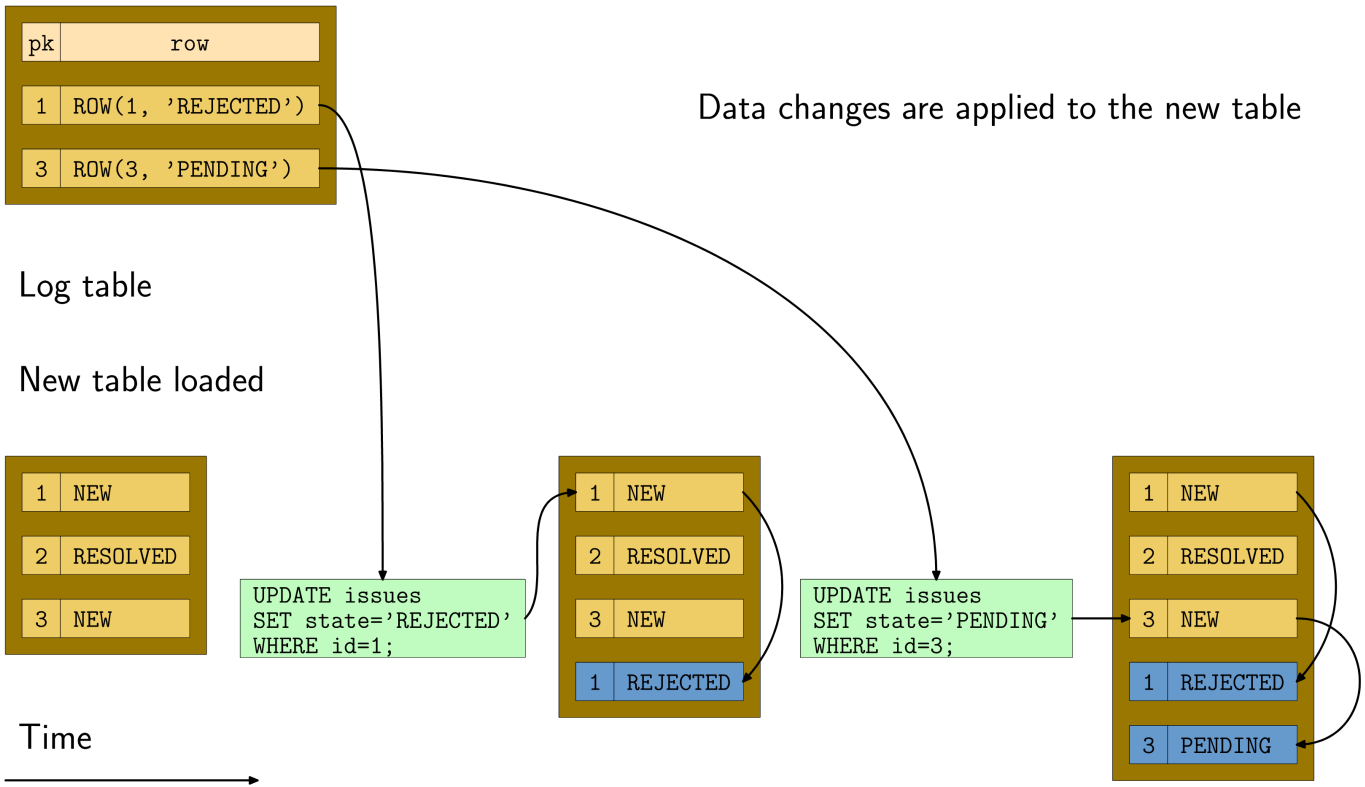
pg_repack

- Forked from pg_reorg in 2012
- Implemented in two parts:
  - A few server-side SQL and C functions
  - Workflow controlled by a client application

pg_repack


Old table
1 NEW
2 RESOLVED
3 NEW
UPDATE issues
SET state='REJECTED'
WHERE id=1;
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
UPDATE issues
SET state='PENDING'
WHERE id=4;
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
3 PENDING
INSERT INTO ... SELECT ... FROM ...
Trigger inserts data changes into log table
pk row
1 ROW(1, 'REJECTED')
3 ROW(3, 'PENDING')
New table
1 NEW
1 NEW
2 RESOLVED
1 NEW
2 RESOLVED
3 NEW
Time

pg_repack


pk
row
1
ROW(1, 'REJECTED')
3
ROW(3, 'PENDING')
Data changes are applied to the new table
Log table
New table loaded
1
NEW
2
RESOLVED
3
NEW
UPDATE issues
SET state='REJECTED'
WHERE id=1;
1
NEW
2
RESOLVED
3
NEW
1
REJECTED
UPDATE issues
SET state='PENDING'
WHERE id=3;
1
NEW
2
RESOLVED
3
NEW
1
REJECTED
3
PENDING
Time

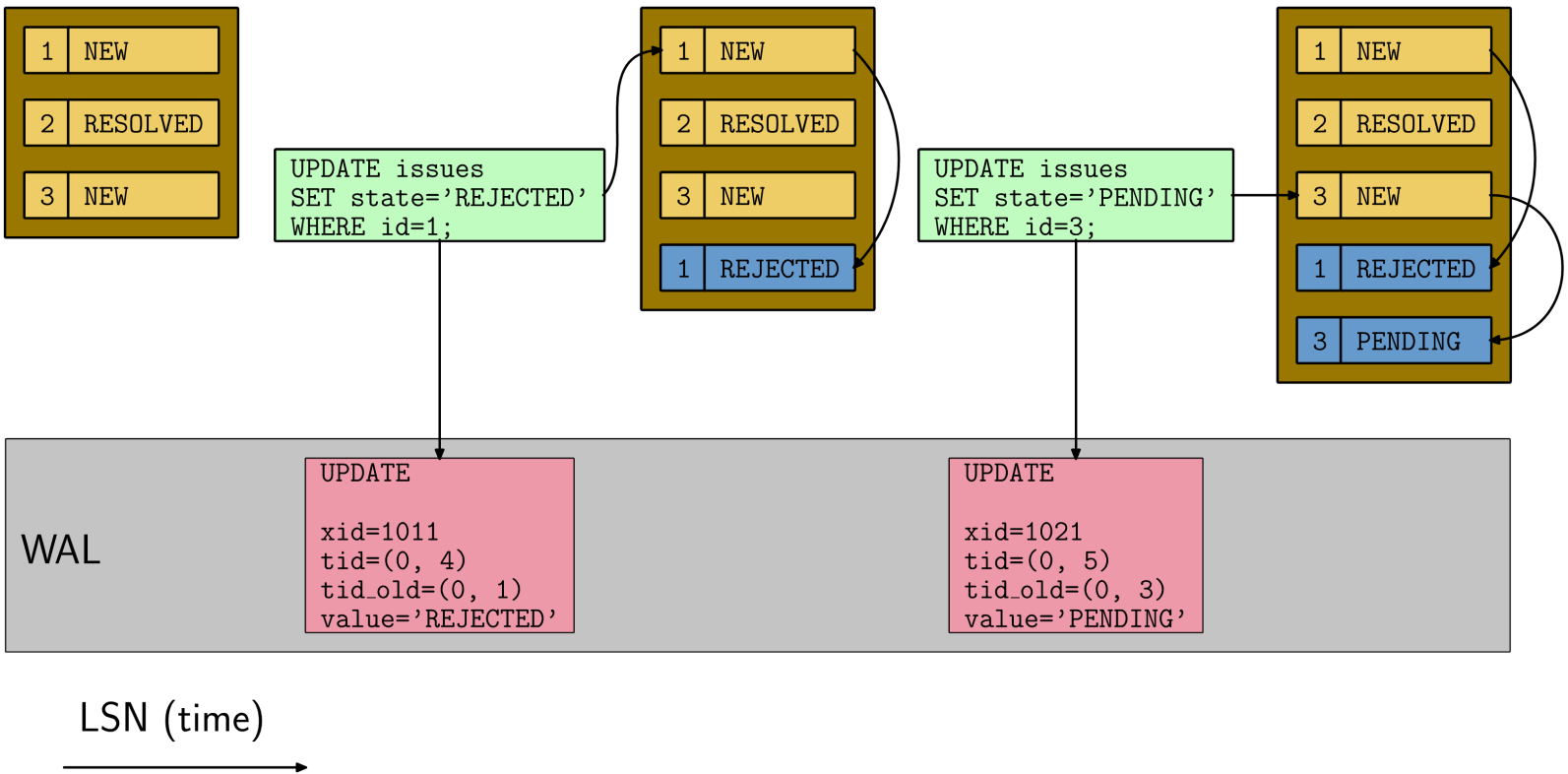
pg_repack's algorithm

- Like `VACUUM FULL`, it removes bloat by copying the useful data to a new table, swaps underlying files and drops the new table.
- Exclusive lock is held during the swap, but possibly a bit longer if the database is very busy.
- Data changes done by applications during the copy are captured by triggers and written to a "log table"; applied after the initial copying and index rebuild, right before the swap.
- Multiple backends can be launched to rebuild indexes

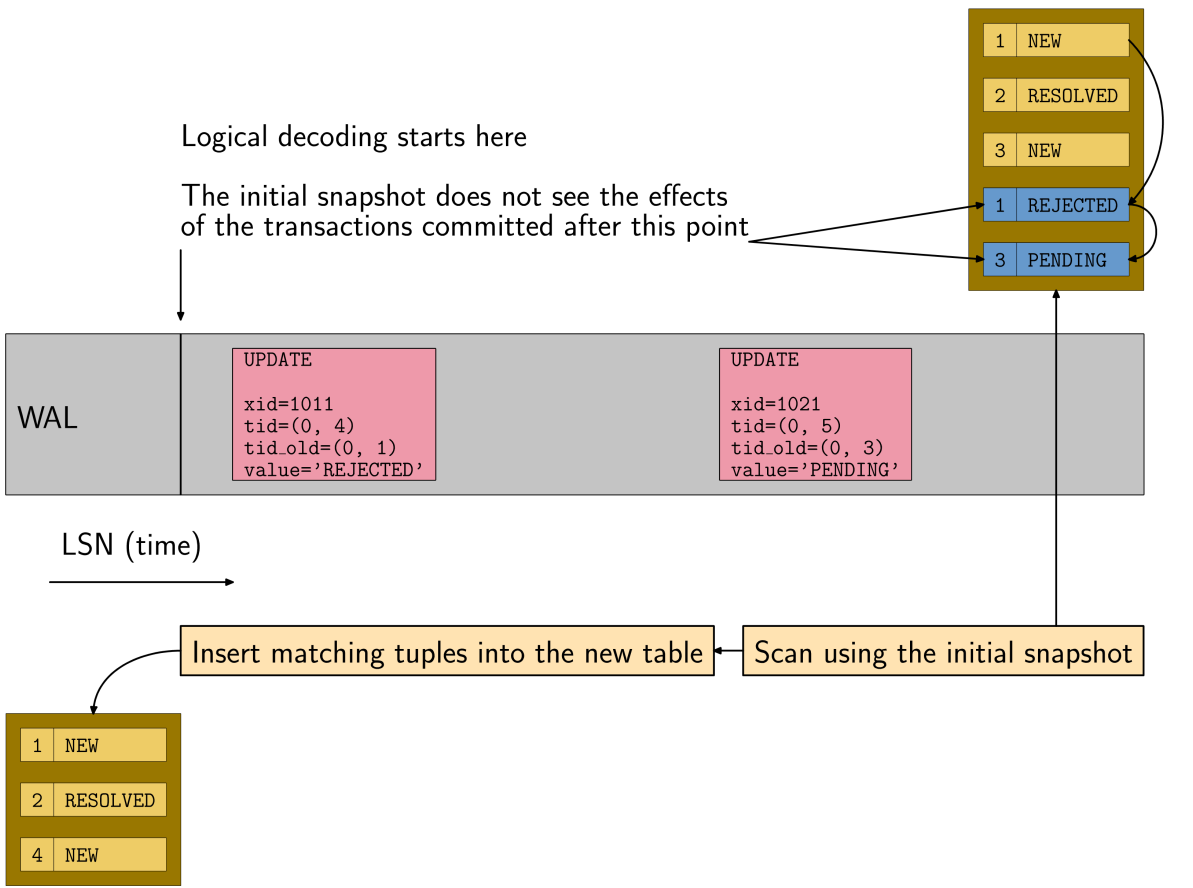
pg_squeeze

- Started in 2016 by Antonin Houska (PostgreSQL 9.5)
- Initial motivation: allow `pg_repack` to be scheduled without external tools
- Use of dual client/server implementation made this difficult
- Realization: better to reimplement everything with modern technology
  - background worker for scheduling (requires server-only code)
  - logical decoding (instead of triggers)
  - binary data rather than text
  - server API rather than SQL commands
- End result: a complete reimplementation

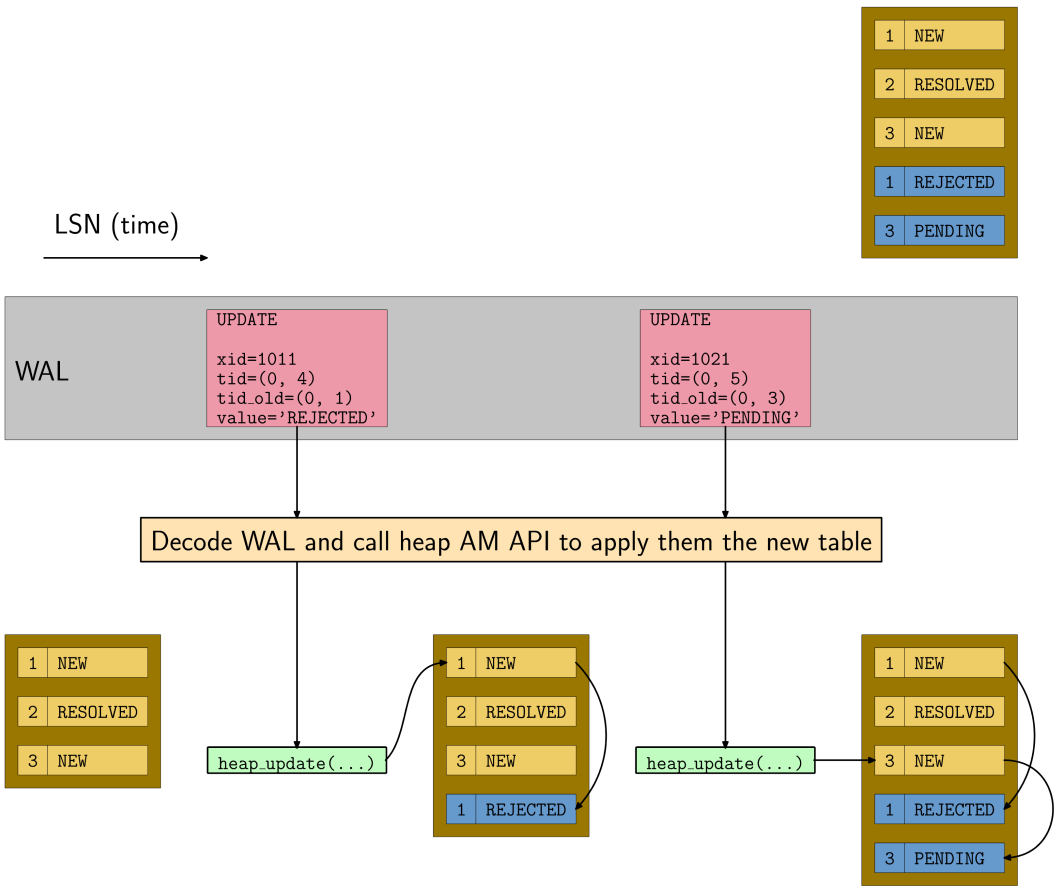
pg_squeeze


1 NEW
2 RESOLVED
3 NEW
UPDATE issues
SET state='REJECTED'
WHERE id=1;
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
UPDATE issues
SET state='PENDING'
WHERE id=3;
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
3 PENDING
WAL
UPDATE
xid=1011
tid=(0, 4)
tid_old=(0, 1)
value='REJECTED'
UPDATE
xid=1021
tid=(0, 5)
tid_old=(0, 3)
value='PENDING'
LSN (time)

pg_squeeze


1 NEW
2 RESOLVED
3 NEW
1 REJECTED
3 PENDING
Logical decoding starts here
The initial snapshot does not see the effects of the transactions committed after this point
WAL
UPDATE
xid=1011
tid=(0, 4)
tid_old=(0, 1)
value='REJECTED'
UPDATE
xid=1021
tid=(0, 5)
tid_old=(0, 3)
value='PENDING'
LSN (time)
Insert matching tuples into the new table
Scan using the initial snapshot
1 NEW
2 RESOLVED
4 NEW

pg_squeeze


1 NEW
2 RESOLVED
3 NEW
1 REJECTED
3 PENDING
LSN (time)
WAL
UPDATE
xid=1011
tid=(0, 4)
tid_old=(0, 1)
value='REJECTED'
UPDATE
xid=1021
tid=(0, 5)
tid_old=(0, 3)
value='PENDING'
Decode WAL and call heap AM API to apply them the new table
1 NEW
2 RESOLVED
3 NEW
heap_update(...)
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
heap_update(...)
1 NEW
2 RESOLVED
3 NEW
1 REJECTED
3 PENDING

pg_squeeze

- cron-like scheduling
  - Squeeze table if the bloat exceeds configured threshold
- Can move tables and indexes to different tablespaces
- Cannot process *unlogged* tables

The REPACK command

- REPACK subsumes CLUSTER and VACUUM FULL

Synopsis

```
REPACK [ ( option [, ...] ) ] [ table_and_columns [ USING INDEX [ index_name ] ] ]

where option can be one of:

    VERBOSE [ boolean ]
    ANALYZE [ boolean ]

and table_and_columns is:

    table_name [ ( column_name [, ...] ) ]
```


Single-table REPACK forms

- single-table `vacuum full`:

```
REPACK (ANALYZE) customers;
```

- single-table `cluster`:

```
REPACK (ANALYZE, VERBOSE) customers USING INDEX cust_pkey;
```

- single-table `cluster` using the stored index:

```
REPACK customers USING INDEX;
```


Full-database REPACK forms

- whole-database VACUUM FULL:

```
REPACK;
```

- whole-database CLUSTER:

```
REPACK USING INDEX;
```


Concurrent REPACK

```
REPACK (ANALYZE, CONCURRENTLY) customers USING INDEX tenant_idx;

REPACK (CONCURRENTLY) orders;

REPACK (CONCURRENTLY) USING INDEX;
```

- This behaves similar to pg_squeeze
- Differences of note:
  - Does not unlock the table before requesting exclusive lock
  - No scheduling

Advantages over pg_squeeze

- Does not require `wal_level=logical`
- Logical decoding by background worker
  - Avoids long WAL accumulation
- Integrated replication slot handling
  `max_repack_replication_slots`
- Integrated deadlock-safe lock upgrade
  (in progress)

- Fully integrated in core
  - Very easy to use
  - Available everywhere

Future work

- Improve historic snapshot creation
- MVCC safety
- Avoid Xmin pinning

- Allow tables/indexes to move tablespace
- Migrate table to another table AM (zheap, OrioleDB, ...)
- Modify `ALTER TABLE` to rewrite tables using concurrent repack

For Those Listening

- Test preview versions
  - Build from git repo branch `master`
  - beta 1 out next week
- Report any problems as open items
- Leave feedback for talk & conference!

Antonin Houska

Thanks for listening!

Questions?

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Leave Feedback!

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