PostgreSQL is an open-source, full-featured relational database. This presentation covers advanced administration topics.

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Outline

1. Installation
2. Configuration
3. Maintenance
4. Monitoring
5. Recovery
1. Installation

- Click-through Installers
  - MS Windows
  - Linux
  - OS X
- Ports
  - RPM
  - DEB
  - PKG
  - other packages
- Source
  - obtaining
  - build options
  - installing
Initialization (initdb)

$ initdb /u/pgsql/data
The files belonging to this database system will be owned by user "postgres".
This user must also own the server process.

The database cluster will be initialized with locale "en_US.UTF-8".
The default database encoding has accordingly been set to "UTF8".
The default text search configuration will be set to "english".

Data page checksums are disabled.

fixing permissions on existing directory /u/pgsql/data ... ok
creating subdirectories ... ok
selecting default max_connections ... 100
selecting default shared_buffers ... 128MB
selecting dynamic shared memory implementation ... posix
creating configuration files ... ok
running bootstrap script ... ok
performing post-bootstrap initialization ... ok
syncing data to disk ... ok

WARNING: enabling "trust" authentication for local connections
You can change this by editing pg_hba.conf or using the option -A, or
--auth-local and --auth-host, the next time you run initdb.

Success. You can now start the database server using:

    pg_ctl -D /u/pgsql/data -l logfile start
pg_controldata

$ pg_controldata
pg_control version number: 1002
Catalog version number: 201707211
Database system identifier: 6544633619067825437
Database cluster state: shut down
pg_control last modified: Sun 15 Apr 2018 07:20:58 AM EDT
Latest checkpoint location: 0/15C09E0
Prior checkpoint location: 0/15C0708
Latest checkpoint's REDO location: 0/15C09E0
Latest checkpoint's REDO WAL file: 000000010000000000000000001
Latest checkpoint's TimeLineID: 1
Latest checkpoint's PrevTimeLineID: 1
Latest checkpoint's full_page_writes: on
Latest checkpoint's NextXID: 0:555
Latest checkpoint's NextOID: 12296
Latest checkpoint's NextMultiXactId: 1
Latest checkpoint's NextMultiOffset: 0
Latest checkpoint's oldestXID: 548
Latest checkpoint's oldestXID's DB: 1
Latest checkpoint's oldestActiveXID: 0
Latest checkpoint's oldestMultiXid: 1
Latest checkpoint's oldestMulti's DB: 1
Latest checkpoint's oldestCommitTsXid: 0
Latest checkpoint's newestCommitTsXid: 0
Time of latest checkpoint: Sun 15 Apr 2018 07:20:58 AM EDT
Fake LSN counter for unlogged rels: 0/1
Minimum recovery ending location: 0/0
Min recovery ending loc's timeline: 0
Backup start location: 0/0
Backup end location: 0/0
End-of-backup record required: no
wal_level setting: replica
wal_log_hints setting: off
max_connections setting: 100
System Architecture

Main

Postmaster

Postgres

Libpq

Libpq

Parse Statement

Utility

Utility Command

Traffic Cop

Rewrite Query

Generate Paths

Optimal Path

Generate Plan

Execute Plan

Utilities

Catalog

Storage Managers

Access Methods

Nodes / Lists

e.g. CREATE TABLE, COPY

SELECT, INSERT, UPDATE, DELETE
Session Creation

Diagram:
- Postmaster
- `fork()`
- Postgres
- Data
- Shared Memory
- Stack
Starting Postmaster

- manually
- `pg_ctl start`
- `on boot`
Stopping Postmaster


- manually
- `pg_ctl stop`
- on shutdown
Connections

- local — unix domain socket
- host — TCP/IP, both SSL or non-SSL
- hostssl — only SSL
- hostnossl — never SSL
Authentication

- trust
- reject
- passwords
  - scram-sha-256
  - md5
  - password (cleartext)
- local authentication
  - socket permissions
  - ’peer’ socket user name passing
  - host ident using local identd
remote authentication
  host ident using pg_ident.conf
  kerberos
    gss
    sspi
  pam
  ldap
  radius
  cert
- hostname and network mask
- database name
- role name (user or group)
- filename or list of databases, role
- IPv6
```plaintext
# TYPE DATABASE USER ADDRESS METHOD

# "local" is for Unix domain socket connections only
local  all  all                trust

# IPv4 local connections:
host  all  all  127.0.0.1/32 trust

# IPv6 local connections:
host  all  all  ::1/128  trust

# Allow replication connections from localhost, by a user with the
# replication privilege.
#local replication postgres       trust
#host  replication postgres  127.0.0.1/32 trust
#host  replication postgres  ::1/128 trust
```
<table>
<thead>
<tr>
<th>TYPE</th>
<th>DATABASE</th>
<th>USER</th>
<th>ADDRESS</th>
<th>METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>all</td>
<td>all</td>
<td>all</td>
<td>trust</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>all</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>127.0.0.1/32</td>
<td>trust</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>::1/128</td>
<td>trust</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>all</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>192.168.1.254/32</td>
<td>reject</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>192.168.1.0/24</td>
<td>scram-sha-256</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.0.0.0/0</td>
<td>reject</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.0.0.0/0</td>
<td>scram-sha-256</td>
</tr>
</tbody>
</table>
Permissions

- Host connection permissions
- Role permissions
  - create roles
  - create databases
  - table permissions
- Database management
  - template1 customization
  - system tables
  - disk space computations
$ ls -CF
base/          pg_ident.conf  pg_serial/  pg_tblspc/  postgresql.auto.conf
global/        pg_logical/   pg_snapshots/ pg_twophase/ postgresql.conf
pg_commit_ts/  pg_multixact/ pg_stat/    PG_VERSION postmaster.opts
pg_dynshmem/   pg_notify/    pg_stat_tmp/ pg_wal/
pg_hba.conf    pg_replslot/  pg_subtrans/ pg_xact/
Database Directories

$ ls -CF global/
1136  1214_fsm  1261_vm  2671  2846  2967  6000_vm
1136_fsm  1214_vm  1262  2672  2846_vm  3592  6001
1136_vm  1232  1262_fsm  2676  2847  3592_vm  6002
1137  1233  1262_vm  2677  2964  3593  pg_control
1213  1260  2396  2694  2964_vm  4060  pg_filenode.map
1213_fsm  1260_fsm  2396_fsm  2695  2965  4060_vm  pg_internal.init
1213_vm  1260_vm  2396_vm  2697  2966  4061
1214  1261  2397  2698  2966_vm  6000

$ ls -CF base/
1/  12406/  12407/  16384/

$ ls -CF base/16384
112  1249_fsm  2606_vm  2652  2699  3081  3598_vm
113  1249_vm  2607  2653  2701  3085  3599
12242  1255  2607_fsm  2654  2702  3118  3600
12242_fsm  1255_fsm  2607_vm  2655  2703  3118_vm  3600_fsm
12242_vm  1255_vm  2608  2656  2704  3119  3600_vm
12244  1259  2608_fsm  2657  2753  3164  3601
12246  1259_fsm  2608_vm  2658  2753_fsm  3256  3601_fsm

...
Transaction/WAL Directories

$ ls -CF pg_wal/
00000001100000000000000001 archive_status/

$ ls -CF pg_xact/
0000
<table>
<thead>
<tr>
<th>$ ls -CF share/</th>
</tr>
</thead>
<tbody>
<tr>
<td>conversion_create.sql</td>
</tr>
<tr>
<td>extension/</td>
</tr>
<tr>
<td>information_schema.sql</td>
</tr>
<tr>
<td>pg_hba.conf.sample</td>
</tr>
<tr>
<td>pg_ident.conf.sample</td>
</tr>
<tr>
<td>pg_service.conf.sample</td>
</tr>
<tr>
<td>postgres.bki</td>
</tr>
<tr>
<td>postgres.description</td>
</tr>
<tr>
<td>postgresql.conf.sample</td>
</tr>
<tr>
<td>postgres.shdescription</td>
</tr>
<tr>
<td>psqlrc.sample</td>
</tr>
<tr>
<td>recovery.conf.sample</td>
</tr>
<tr>
<td>snowball_create.sql</td>
</tr>
<tr>
<td>sql_features.txt</td>
</tr>
<tr>
<td>system_views.sql</td>
</tr>
<tr>
<td>timezone/</td>
</tr>
<tr>
<td>timezonesets/</td>
</tr>
<tr>
<td>tsearch_data/</td>
</tr>
</tbody>
</table>
2. Configuration

https://www.flickr.com/photos/mwichary/
# -----------------------------
# PostgreSQL configuration file
# -----------------------------
#
# This file consists of lines of the form:
#
#   name = value
#
# (The "=" is optional.) Whitespace may be used. Comments are introduced with
# "#" anywhere on a line. The complete list of parameter names and allowed
# values can be found in the PostgreSQL documentation.
#
# The commented-out settings shown in this file represent the default values.
# Re-commenting a setting is NOT sufficient to revert it to the default value;
# you need to reload the server.
This file is read on server startup and when the server receives a SIGHUP signal. If you edit the file on a running system, you have to SIGHUP the server for the changes to take effect, run "pg_ctl reload", or execute "SELECT pg_reload_conf()". Some parameters, which are marked below, require a server shutdown and restart to take effect.

Any parameter can also be given as a command-line option to the server, e.g., "postgres -c log_connections=on". Some parameters can be changed at run time with the "SET" SQL command.

Memory units: kilobytes, megabytes, gigabytes, terabytes

Time units: milliseconds, seconds, minutes, hours, days
# The default values of these variables are driven from the -D command-line
# option or PGDATA environment variable, represented here as ConfigDir.

#data_directory = 'ConfigDir'  # use data in another directory
   # (change requires restart)
#hba_file = 'ConfigDir/pg_hba.conf'  # host-based authentication file
   # (change requires restart)
#ident_file = 'ConfigDir/pg_ident.conf'  # ident configuration file
   # (change requires restart)

# If external_pid_file is not explicitly set, no extra PID file is written.
#external_pid_file = ''  # write an extra PID file
   # (change requires restart)
Connections and Authentication

```bash
#listen_addresses = 'localhost'

#port = 5432
max_connections = 100
#superuser_reserved_connections = 3
#unix_socket_directories = '/tmp'

#unix_socket_group = ''
#unix_socket_permissions = 0777

#bonjour = off

#bonjour_name = ''
```

# what IP address(es) to listen on;
# comma-separated list of addresses;
# defaults to 'localhost'; use '*' for all
# (change requires restart)
# (change requires restart)
# (change requires restart)

# advertise server via Bonjour
# (change requires restart)
# defaults to the computer name
# (change requires restart)
Security and Authentication

#authentication_timeout = 1min    # 1s-600s
#ssl = off
#ssl_ciphers = 'HIGH:MEDIUM:+3DES:!aNULL'  # allowed SSL ciphers
#ssl_prefer_server_ciphers = on
#ssl_ecdh_curve = 'prime256v1'
#ssl_dh_params_file = ''
#ssl_cert_file = 'server.crt'
#ssl_key_file = 'server.key'
#ssl_ca_file = ''
#ssl_crl_file = ''
#password_encryption = md5        # md5 or scram-sha-256
#db_user_namespace = off
#row_security = on

# GSSAPI using Kerberos
#krb_server_keyfile = ''
#krb_caseins_users = off
TCP/IP Control

#tcp_keepalives_idle = 0
# TCP_KEEPIDLE, in seconds;
# 0 selects the system default

#tcp_keepalives_interval = 0
# TCP_KEEPINTVL, in seconds;
# 0 selects the system default

#tcp_keepalives_count = 0
# TCP_KEEPCNT;
shared_buffers = 128MB

#huge_pages = try

#temp_buffers = 8MB
#max_prepared_transactions = 0

# Caution: it is not advisable to set max_prepared_transactions nonzero unless
# you actively intend to use prepared transactions.
#work_mem = 4MB
#maintenance_work_mem = 64MB
#replacement_sort_tuples = 150000
#autovacuum_work_mem = -1
#max_stack_depth = 2MB
dynamic_shared_memory_type = posix

# min 128kB
# (change requires restart)
# on, off, or try
# (change requires restart)
# min 800kB
# zero disables the feature
# (change requires restart)
# min 64kB
# min 1MB
# limits use of replacement selection sort
# min 1MB, or -1 to use maintenance_work_mem
# min 100kB
# the default is the first option
# supported by the operating system:
# posix
# sysv
# windows
# mmap
# use none to disable dynamic shared memory
# (change requires restart)
Memory Usage (Continued)

Query and Checkpoint Operations

PostgreSQL Shared Buffer Cache

Kernel Disk Buffer Cache

Transaction Durability

Write-Ahead Log

fsync

Recovery
## Sizing Shared Memory

<table>
<thead>
<tr>
<th></th>
<th>RAM</th>
<th>Swap</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free</td>
<td>Kernel</td>
<td>Page In (bad)</td>
</tr>
<tr>
<td>Shared Buffer Cache (shared_buffers)</td>
<td>Page Out</td>
<td></td>
</tr>
<tr>
<td>Postgres Session (work_mem)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postgres Session (work_mem)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Page In (bad)
- Page Out
# - Disk -

```
#temp_file_limit = -1 # limits per-process temp file space
# in kB, or -1 for no limit
```

# - Kernel Resource Usage -

```
#max_files_per_process = 1000 # min 25
#shared_preload_libraries = '' # (change requires restart)
```
Vacuum and Background Writer

# - Cost-Based Vacuum Delay -

#vacuum_cost_delay = 0  # 0-100 milliseconds
#vacuum_cost_page_hit = 1  # 0-10000 credits
#vacuum_cost_page_miss = 10  # 0-10000 credits
#vacuum_cost_page_dirty = 20  # 0-10000 credits
#vacuum_cost_limit = 200  # 1-10000 credits

# - Background Writer -

#bgwriter_delay = 200ms  # 10-10000ms between rounds
#bgwriter_lru_maxpages = 100  # 0-1000 max buffers written/round
#bgwriter_lru_multiplier = 2.0  # 0-10.0 multiplier on buffers scanned/round
#bgwriter_flush_after = 512kB  # measured in pages, 0 disables

# - Asynchronous Behavior -

#effective_io_concurrency = 1  # 1-1000; 0 disables prefetching
#max_worker_processes = 8  # (change requires restart)
#max_parallel_workers_per_gather = 2  # taken from max_parallel_workers
#max_parallel_workers = 8  # maximum number of max_worker_processes that can be used in parallel queries
#old_snapshot_threshold = -1  # 1min-60d; -1 disables; 0 is immediate
Write-Ahead Log (WAL)

```plaintext
#wal_level = replica
# minimal, replica, or logical
# (change requires restart)
# flush data to disk for crash safety
# (turning this off can cause
# unrecoverable data corruption)
# synchronous_commit = on # synchronization level;
# off, local, remote_write, remote_apply, or
# the default is the first option
# supported by the operating system:
# open_datasync
# fdatasync (default on Linux)
# fsync
# fsync_writethrough
# open_sync
# recover from partial page writes
# enable compression of full-page writes
# also do full page writes of non-critical
# (change requires restart)
# min 32kB, -1 sets based on shared_buffers
# (change requires restart)
# 1-10000 milliseconds
# measured in pages, 0 disables

#full_page_writes = on
#wal_compression = off
#wal_log_hints = off

#wal_buffers = -1
# min 32kB, -1 sets based on shared_buffers

#wal_writer_delay = 200ms
# 1-10000 milliseconds

#commit_delay = 0
# range 0-100000, in microseconds

#commit_siblings = 5
# range 1-1000
```
Write-Ahead Logging (Continued)

Query and Checkpoint Operations

PostgreSQL Shared Buffer Cache

Kernel Disk Buffer Cache

Disk Blocks

Transaction Durability

Write-Ahead Log

f sync

f sync

Recovery

Postgres Backend

Postgres Backend

Postgres Backend

Backend

Postgres

Backend

Backend

Backend

Backend

Backend

Backend

Backend

Backend
# Checkpoints and Archiving

# Checkpoint Timeout
#checkpoint_timeout = 5min  # range 30s-1d
#max_wal_size = 1GB
#min_wal_size = 80MB
#checkpoint_completion_target = 0.5  # checkpoint target duration, 0.0 - 1.0
#checkpoint_flush_after = 256kB  # measured in pages, 0 disables
#checkpoint_warning = 30s  # 0 disables

# Archiving

#archive_mode = off  # enables archiving; off, on, or always
#archive_command = ''  # (change requires restart)
# archive command to use to archive a logfile segment
# placeholders: %p = path of file to archive
# %f = file name only
# e.g., 'test ! -f /mnt/server/archivedir/%f && cp
#archive_timeout = 0  # force a logfile segment switch after this
# number of seconds; 0 disables
Write-Ahead Logging (Continued)

PostgreSQL Shared Buffer Cache

Begin 1

End 1

Rotate

Write-Ahead Log
# Set these on the master and on any standby that will send replication data.

```bash
#max_wal_senders = 10 # max number of walsender processes
#wal_keep_segments = 0 # in logfile segments, 16MB each; 0 disables
#wal_sender_timeout = 60s # in milliseconds; 0 disables

#max_replication_slots = 10 # max number of replication slots
#track_commit_timestamp = off # collect timestamp of transaction commit
```
# These settings are ignored on a standby server.

#synchronous_standby_names = '' # standby servers that provide sync rep
# method to choose sync standbys, number of sync standbys,
# and comma-separated list of application_name
# from standby(s); '*' = all

#vacuum_defer_cleanup_age = 0 # number of xacts by which cleanup is delayed
Standby Replication Server

# These settings are ignored on a master server.

#hot_standby = on
# "off" disallows queries during recovery
# (change requires restart)
#max_standby_archive_delay = 30s
# max delay before canceling queries
# when reading WAL from archive;
# -1 allows indefinite delay
#max_standby_streaming_delay = 30s
# max delay before canceling queries
# when reading streaming WAL;
# -1 allows indefinite delay
#wal_receiver_status_interval = 10s
# send replies at least this often
# 0 disables
#hot_standby_feedback = off
# send info from standby to prevent
# query conflicts
#wal_receiver_timeout = 60s
# time that receiver waits for
# communication from master
# in milliseconds; 0 disables
#wal_retrieve_retry_interval = 5s
# time to wait before retrying to
# retrieve WAL after a failed attempt
These settings are ignored on a publisher.

```plaintext
#max_logical_replication_workers = 4  # taken from max_worker_processes
# (change requires restart)
#max_sync_workers_per_subscription = 2  # taken from max_logical_replication_workers
```
#enable_bitmapscan = on
#enable_hashagg = on
#enable_hashjoin = on
#enable_indexscan = on
#enable_indexonlyscan = on
#enable_material = on
#enable_mergejoin = on
#enable_nestloop = on
#enable_seqscan = on
#enable_sort = on
#enable_tidscan = on
**Planner Constants**

```plaintext
#seq_page_cost = 1.0  # measured on an arbitrary scale
#random_page_cost = 4.0  # same scale as above
#cpu_tuple_cost = 0.01  # same scale as above
#cpu_index_tuple_cost = 0.005  # same scale as above
#cpu_operator_cost = 0.0025  # same scale as above
#parallel_tuple_cost = 0.1  # same scale as above
#parallel_setup_cost = 1000.0  # same scale as above
#min_parallel_table_scan_size = 8MB
#min_parallel_index_scan_size = 512kB
#effective_cache_size = 4GB
```
#geqo = on
#geqo_threshold = 12
#geqo_effort = 5
#geqo_pool_size = 0
#geqo_generations = 0
#geqo_selection_bias = 2.0
#geqo_seed = 0.0
#default_statistics_target = 100
#constraint_exclusion = partition
#cursor_tuple_fraction = 0.1
#from-collapse_limit = 8
#join-collapse_limit = 8

#force_parallel_mode = off

# range 1-10000
# on, off, or partition
# range 0.0-1.0
# 1 disables collapsing of explicit
# JOIN clauses
# log_destination = 'stderr'
# Valid values are combinations of stderr, csvlog, syslog, and eventlog, depending on platform. csvlog requires logging_collector to be on.

# This is used when logging to stderr:
#logging_collector = off
# Enable capturing of stderr and csvlog into log files. Required to be on for csvlogs.
# (change requires restart)

# These are only used if logging_collector is on:
#log_directory = 'log'
# directory where log files are written, can be absolute or relative to PGDATA
#log_filename = 'postgresql-%Y-%m-%d_%H%M%S.log'
# log file name pattern, can include strftime() escapes
#log_file_mode = 0600
# creation mode for log files, begin with 0 to use octal notation
#log_truncate_on_rotation = off

# If on, an existing log file with the same name as the new log file will be truncated rather than appended to.
# But such truncation only occurs on time-driven rotation, not on restarts or size-driven rotation. Default is off, meaning append to existing files in all cases.

#log_rotation_age = 1d

# Automatic rotation of logfiles will happen after that time. 0 disables.

#log_rotation_size = 10MB

# Automatic rotation of logfiles will happen after that much log output. 0 disables.
Where to Log (syslog)

#syslog_facility = 'LOCAL0'
#syslog_ident = 'postgres'
#syslog_sequence_numbers = on
#syslog_split_messages = on

# This is only relevant when logging to eventlog (win32):
# (change requires restart)
#event_source = 'PostgreSQL'
When to Log

#client_min_messages = notice
# values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   log
#   notice
#   warning
#   error

#log_min_messages = warning
# values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   info
#   notice
#   warning
#   error
#   log
#   fatal
#   panic
When to Log (Continued)

#log_min_error_statement = error  # values in order of decreasing detail:
#   debug5
#   debug4
#   debug3
#   debug2
#   debug1
#   info
#   notice
#   warning
#   error
#   log
#   fatal
#   panic (effectively off)

#log_min_duration_statement = -1  # -1 is disabled, 0 logs all statements
# and their durations, > 0 logs only
# statements running at least this number
# of milliseconds
#debug_print_parse = off
#debug_print_rewritten = off
#debug_print_plan = off
#debug_pretty_print = on
#log_checkpoints = off
#log_connections = off
#log_disconnections = off
#log_duration = off
#log_error_verbosity = default  # terse, default, or verbose messages
#log_hostname = off

What to Log
#log_line_prefix = '%m [%p]' 

# special values:
# %a = application name
# %u = user name
# %d = database name
# %r = remote host and port
# %h = remote host
# %p = process ID
# %t = timestamp without milliseconds
# %m = timestamp with milliseconds
# %n = timestamp with milliseconds (as a
# %i = command tag
# %e = SQL state
# %c = session ID
# %l = session line number
# %s = session start timestamp
# %v = virtual transaction ID
# %x = transaction ID (0 if none)
# %q = stop here in non-session processes
# % = '
# e.g., '<%u%%%d> '
#log_lock_waits = off
#log_statement = 'none'
#log_replication_commands = off
#log_temp_files = -1

log_timezone = 'US/Eastern'

# - Process Title -

#cluster_name = ''

#update_process_title = on

# log lock waits >= deadlock_timeout
# none, ddl, mod, all

# log temporary files equal or larger
# than the specified size in kilobytes;
# -1 disables, 0 logs all temp files

# added to process titles if nonempty
# (change requires restart)
# - Query/Index Statistics Collector -

#track_activities = on
#track_counts = on
#track_io_timing = off
#track_functions = none # none, pl, all
#track_activity_query_size = 1024 # (change requires restart)
#stats_temp_directory = 'pg_stat_tmp'

# - Statistics Monitoring -

#log_parser_stats = off
#log_planner_stats = off
#log_executor_stats = off
#log_statement_stats = off
#log_statement_stats = off
#autovacuum = on

#log_autovacuum_min_duration = -1

#autovacuum_max_workers = 3

#autovacuum_naptime = 1min
#autovacuum_vacuum_threshold = 50

#autovacuum_analyze_threshold = 50

#autovacuum_vacuum_scale_factor = 0.2
#autovacuum_analyze_scale_factor = 0.1
#autovacuum_freeze_max_age = 200000000

#autovacuum_multixact_freeze_max_age = 400000000

#autovacuum_vacuum_cost_delay = 20ms

#autovacuum_vacuum_cost_limit = -1
Statement Behavior

#search_path = '"$user", public' # schema names
#default_tablespace = '' # a tablespace name, '' uses the default
#temp_tablespaces = '' # a list of tablespace names, '' uses
# only default tablespace

#check_function_bodies = on
#default_transaction_isolation = 'read committed'
#default_transaction_read_only = off
#default_transaction_deferrable = off
#session_replication_role = 'origin'
#statement_timeout = 0 # in milliseconds, 0 is disabled
#lock_timeout = 0 # in milliseconds, 0 is disabled
#idle_in_transaction_session_timeout = 0 # in milliseconds, 0 is disabled
#vacuum_freeze_min_age = 50000000
#vacuum_freeze_table_age = 150000000
#vacuum_multixact_freeze_min_age = 5000000
#vacuum_multixact_freeze_table_age = 150000000
#bytea_output = 'hex' # hex, escape
#xmlbinary = 'base64'
#xmloption = 'content'
#gin_fuzzy_search_limit = 0
#gin_pending_list_limit = 4MB
locale, formatting, and full text search

datestyle = 'iso, mdy'
#intervalstyle = 'postgres'
timezone = 'US/Eastern'
#timezone_abbreviations = 'Default'

#extra_float_digits = 0
#client_encoding = sql_ascii

# These settings are initialized by initdb, but they can be changed.
lc_messages = 'en_US.UTF-8'  # locale for system error message

lc_monetary = 'en_US.UTF-8'  # locale for monetary formatting
lc_numeric = 'en_US.UTF-8'  # locale for number formatting
lc_time = 'en_US.UTF-8'  # locale for time formatting
# default configuration for text search
default_text_search_config = 'pg_catalog.english'
# Other Defaults

```python
#dynamic_library_path = '$libdir'
#local_preload_libraries = ''
#session_preload_libraries = ''
```
Lock Management

```plaintext
#deadlock_timeout = 1s
#max_locks_per_transaction = 64
#max_pred_locks_per_transaction = 64
#max_pred_locks_per_relation = -2
#max_pred_locks_per_page = 2
```
# - Previous PostgreSQL Versions -

```python
#array_nulls = on
#backslash_quote = safe_encoding                       # on, off, or safe_encoding
#default_with_oids = off
#escape_string_warning = on
#lo_compat_privileges = off
#operator_precedence_warning = off
#quote_all_identifiers = off
#standard_conforming_strings = on
#synchronize_seqscans = on
```

# - Other Platforms and Clients -

```python
#transform_null_equals = off
```
# Error Handling

#exit_on_error = off  # terminate session on any error?
#restart_after_crash = on  # reinitialize after backend crash?
#include_dir = 'conf.d'
#include_if_exists = 'exists.conf'
#include = 'special.conf'

# include files ending in '.conf' from # directory 'conf.d'
# include file only if it exists
# include file
Interfaces

- Installing
  - Compiled Languages (C, ecpg)
  - Scripting Language (Perl, Python, PHP)
  - SPI

- Connection Pooling
Include Files

```
$ ls -CF include/
ecpg_config.h  libpq/   pgtypes_date.h  sql3types.h
ecpgerrno.h     libpq-events.h pgtypes_error.h  sqlca.h
ecpg_informix.h libpq-fe.h  pgtypes_interval.h sqlda-compat.h
ecpglib.h       pg_config_ext.h pgtypes_numeric.h sqlda.h
ecpgtype.h      pg_config.h  pgtypes_timestamp.h sqlda-native.h
informix/       pg_config_manual.h postgres_ext.h
internal/       pg_config_os.h  server/
```
$ ls -CF lib/
ascii_and_mic.so*      libpgcommon.a      utf8_and_ascii.so*
cyrillic_and_mic.so*   libpgfeutils.a      utf8_and_big5.so*
dict_snowball.so*     libpgport.a        utf8_and_cyrillic.so*
euc2004_sjis2004.so*   libpgtypes.a        utf8_and_euc2004.so*
euc_cn_and_mic.so*    libpgtypes.so@       utf8_and_euc_cn.so*
euc_jp_and_sjis.so*    libpgtypes.so.3@    utf8_and_euc_jp.so*
euc_kr_and_mic.so*    libpgtypes.so.3.10*   utf8_and_euc_kr.so*
euc_tw_and_big5.so*   libpq.a            utf8_and_euc_tw.so*
latin2_and_win1250.so*  libpq.so@          utf8_and_gb18030.so*
latin_and_mic.so*     libpq.so.5@         utf8_and_gbk.so*
libecpg.a            libpq.so.5.10*      utf8_and_iso8859_1.so*
libecpg_compat.a     libpqwalreceiver.so* utf8_and_iso8859.so*
libecpg_compat.so@   pgoutput.so*       utf8_and_johab.so*
libecpg_compat.so.3@  pgxs/             utf8_and_sjis2004.so*
libecpg_compat.so.3.10* pkgconfig/        utf8_and_sjis.so*
libecpg.so@          plperl.so*         utf8_and_uhc.so*
libecpg.so.6@        plpgsql.so*        utf8_and_uhc.so*
libecpg.so.6.10*     plpython2.so*
3. Maintenance
Backup

- File system-level (physical)
  - tar, cpio while shutdown
  - file system snapshot
  - rsync, shutdown, rsync, restart
- pg_dump/pg_dumpall (logical)
- Restore/pg_restore with custom format
Continuous Archiving / Point-In-Time Recovery (PITR)

File System−Level Backup  Continuous Archive (WAL)

02:00  09:00  11:00  13:00
1. `archive_mode = on`
2. `wal_level = archive`
3. `archive_command = 'cp -i %p /mnt/server/pgsql/%f < /dev/null'`
4. `SELECT pg_start_backup('label');`
5. Perform file system-level backup (can be inconsistent)
6. `SELECT pg_stop_backup();`

`pg_basebackup` does this automatically.
PITR Recovery

File System−Level Backup

Continuous Archive (WAL)

WAL
PITR Recovery Procedures

1. Stop postmaster
2. Restore file system-level backup
3. Make adjustments as outlined in the documentation
4. Create recovery.conf
5. `restore_command = 'cp /mnt/server/pgsql/%f %p'`
6. Start the postmaster
Continuous Archive Management

Simplify backups and WAL archive file management with:

- *pgBackRest*
- *barman*
Data Maintenance

- **VACUUM** (nonblocking) records free space into .fsm (free space map) files
- **ANALYZE** collects optimizer statistics
- **VACUUM FULL** (blocking) shrinks the size of database disk files
Autovacuum handles vacuum and analyze tasks automatically.
Checkpoints

- Write all dirty shared buffers
- Sync all dirty kernel buffers
- Recycle WAL files
- Controlled by `checkpoint_timeout` and `max_wal_size`
4. Monitoring
$ ps -f -Upostgres
postgresql 825   1   0 Tue12AM ?? 0:06.57 /u/pgsql/bin/postmaster -i
postgresql 829  825   0 Tue12AM ?? 0:35.03 writer process (postmaster)
postgresql 830  825   0 Tue12AM ?? 0:16.07 wal writer process (postmaster)
postgresql 831  825   0 Tue12AM ?? 0:11.34 autovacuum launcher process (postmaster)
postgresql 832  825   0 Tue12AM ?? 0:07.63 stats collector process (postmaster)
postgresql 13003  825   0 3:44PM ?? 0:00.01 postgres test [local] idle (postmaster)
postgresql 13002 12997  0 3:44PM ttyq1 0:00.03 /u/pgsql/bin/psql test
$ top -c

top - 10:29:47 up 23 days, 18:53, 6 users, load average: 1.73, 1.49, 0.81
Tasks: 387 total, 2 running, 385 sleeping, 0 stopped, 0 zombie
%Cpu(s):  5.9 us, 0.5 sy, 0.0 ni, 93.7 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
KiB Mem: 24734444 total, 19187724 used, 5546720 free, 532280 buffers
KiB Swap: 6369276 total, 168292 used, 6200984 free. 16936936 cached Mem

PID USER PR NI VIRT RES SHR S %CPU %MEM TIME+ COMMAND
32037 postgres 20 0 190980 27940 21420 R 100.0 0.1 0:09.74 postgres: postgres test [local] INSERT
32061 root    20 0 26056 3240 2444 R 0.7 0.0 0:00.09 top -c
Query Monitoring

test=> SELECT * FROM pg_stat_activity;
...
<p>| datid  | 16384 |
| datname | test  |
| pid    | 16382 |
| usesysid | 10   |
| usename | postgres |
| application_name | psql |
| client_addr |    |
| client_hostname |    |
| client_port | -1   |
| backend_start | 2018-04-15 09:00:26.467813-04 |
| xact_start | 2018-04-15 09:00:48.028667-04 |
| query_start | 2018-04-15 09:00:48.028667-04 |
| state_change | 2018-04-15 09:00:48.028671-04 |
| wait_event_type |    |
| wait_event |    |
| state | active |
| backend_xid |    |
| backend_xmin | 556 |
| query | SELECT * FROM pg_stat_activity; |
| backend_type | client_backend |</p>
<table>
<thead>
<tr>
<th>Function</th>
<th>Type</th>
<th>Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>pg_stat_all_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_all_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_database</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_sys_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_sys_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_user_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_stat_user_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_all_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_all_sequences</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_all_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_sys_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_sys_sequences</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_sys_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_user_indexes</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_user_sequences</td>
<td>view</td>
<td>postgres</td>
</tr>
<tr>
<td>pg_statio_user_tables</td>
<td>view</td>
<td>postgres</td>
</tr>
</tbody>
</table>
test=> SELECT * FROM pg_stat_database;
...
- [ RECORD 4 ]-+----------
datid | 16384
datname | test
numbackends | 1
xact_commit | 188
xact_rollback | 0
blks_read | 95
blks_hit | 11832
tup_returned | 64389
tup_fetched | 2938
tup_inserted | 0
tup_updated | 0
tup_deleted | 0
### Table Activity

```sql
test=> SELECT * FROM pg_stat_all_tables;
-[ RECORD 10 ]------------------------
  relid | 2616
 schemaname | pg_catalog
 relname | pg_opclass
 seq_scan | 2
 seq_tup_read | 2
 idx_scan | 99
 idx_tup_fetch | 99
 n_tup_ins | 0
 n_tup_upd | 0
 n_tup_del | 0
 n_tup_hot_upd | 0
 n_live_tup | 0
 n_dead_tup | 0
 last_vacuum | 
 last_autovacuum | 
 last_analyze | 
 last_autoanalyze | 
```

81/113
Table Block Activity

test=> SELECT * FROM pg_statio_all_tables;
-[ RECORD 50 ]----------------------------------------
relid | 2602
schemaname | pg_catalog
relname | pg_amop
heap_blks_read | 3
heap_blks_hit | 114
idx_blks_read | 5
idx_blks_hit | 303
toast_blks_read | 
toast_blks_hit | 
tidx_blks_read | 
tidx_blks_hit |
Analyzing Activity

- Heavily used tables
- Unnecessary indexes
- Additional indexes
- Index usage
- TOAST usage
```plaintext
$ vmstat 5

|   | r | b | w | avm | fre | flt | re | pi | po | fr | sr | s0 | s0 | in | sy | cs | us | sy | id |
|---|---|---|---|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | 0 | 0 | 0 | 501820 | 48520 | 1234 | 86 | 2 | 0 | 0 | 3 | 5 | 0 | 263 | 2881 | 599 | 10 | 4 | 86 |
| 3 | 0 | 0 | 0 | 512796 | 46812 | 1422 | 201 | 12 | 0 | 0 | 0 | 3 | 0 | 259 | 6483 | 827 | 4 | 7 | 88 |
| 3 | 0 | 0 | 0 | 542260 | 44356 | 788 | 137 | 6 | 0 | 0 | 0 | 8 | 0 | 286 | 5698 | 741 | 2 | 5 | 94 |
| 4 | 0 | 0 | 0 | 539708 | 41868 | 576 | 65 | 13 | 0 | 0 | 0 | 4 | 0 | 273 | 5721 | 819 | 16 | 4 | 80 |
| 4 | 0 | 0 | 0 | 547200 | 32964 | 454 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 253 | 5736 | 948 | 50 | 4 | 46 |
| 4 | 0 | 0 | 0 | 556140 | 23884 | 461 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 249 | 5917 | 959 | 52 | 3 | 44 |
| 1 | 0 | 0 | 0 | 535136 | 46280 | 1056 | 141 | 25 | 0 | 0 | 0 | 2 | 0 | 261 | 6417 | 890 | 24 | 6 | 70 |
```
### I/O

```bash
$ iostat 5
```

<table>
<thead>
<tr>
<th>tty</th>
<th>tin</th>
<th>tout</th>
<th>sps</th>
<th>tps</th>
<th>msps</th>
<th>sps</th>
<th>tps</th>
<th>msps</th>
<th>sps</th>
<th>tps</th>
<th>msps</th>
<th>usr</th>
<th>nic</th>
<th>sys</th>
<th>int</th>
<th>idl</th>
<th>% cpu</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>119</td>
<td>244</td>
<td>11</td>
<td>6.1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>27.3</td>
<td>0</td>
<td>0</td>
<td>18.1</td>
<td>9</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>86</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>86</td>
<td>20</td>
<td>1</td>
<td>1.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>96</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>82</td>
<td>61</td>
<td>4</td>
<td>3.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>65</td>
<td>6</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>90</td>
<td>31</td>
<td>2</td>
<td>5.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>173</td>
<td>6</td>
<td>0</td>
<td>4.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>48</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>91</td>
<td>3594</td>
<td>63</td>
<td>4.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>11</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>
test=> \df *size*

<table>
<thead>
<tr>
<th>Schema</th>
<th>Name</th>
<th>Result data type</th>
<th>Argument data types</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>pg_catalog</td>
<td>pg_column_size</td>
<td>integer</td>
<td>&quot;any&quot;</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_database_size</td>
<td>bigint</td>
<td>name</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_database_size</td>
<td>bigint</td>
<td>oid</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_indexes_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_relation_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_relation_size</td>
<td>bigint</td>
<td>regclass, text</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_size_pretty</td>
<td>text</td>
<td>bigint</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_table_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_tablespace_size</td>
<td>bigint</td>
<td>name</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_tablespace_size</td>
<td>bigint</td>
<td>oid</td>
<td>normal</td>
</tr>
<tr>
<td>pg_catalog</td>
<td>pg_total_relation_size</td>
<td>bigint</td>
<td>regclass</td>
<td>normal</td>
</tr>
</tbody>
</table>
$ oid2name
All databases:
---------------------------------
18720  = test1
1      = template1
18719  = template0
18721  = test
18735  = postgres
18736  = cssi
Table File Mapping

$ cd /usr/local/pgsql/data/base
$ oid2name
All databases:
---------------------------------
16817  = test2
16578  = x
16756  = test
1       = template1
16569  = template0
16818  = test3
16811  = floattest

$ cd 16756
$ ls 1873*
18730  18731  18732  18735  18736  18737  18738  18739
$ oid2name -d test -o 18737
Tablename of oid 18737 from database "test":
---------------------------------
18737 = ips

$ oid2name -d test -t ips
Oid of table ips from database "test":
---------------------------------
18737 = ips

$ # show disk usage per database
$ cd /usr/local/pgsql/data/base
$ du -s * | > while read SIZE OID >   do >     echo "$SIZE `oid2name -q | grep ^$OID' `~" >   done | > sort -rn 2256 18721 = test
2135 18735 = postgres
Disk Balancing

- Move pg_wal to another drive using symlinks
- Tablespaces
Per-Database Tablespaces

DB1 -> Disk 1
DB2 -> Disk 2
DB3 -> Disk 2
DB4 -> Disk 3
Per-Object Tablespaces

tab1  tab2  index  constraint

Disk 1  Disk 2  Disk 3
## Analyzing Locking

```bash
$ ps -f -Upostgres

<table>
<thead>
<tr>
<th>PID</th>
<th>TT</th>
<th>STAT</th>
<th>TIME</th>
<th>COMMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>9874</td>
<td>??</td>
<td>I</td>
<td>0:00.07</td>
<td>postgres test [local] idle in transaction (postmaster)</td>
</tr>
<tr>
<td>9835</td>
<td>??</td>
<td>S</td>
<td>0:00.05</td>
<td>postgres test [local] UPDATE waiting (postmaster)</td>
</tr>
<tr>
<td>10295</td>
<td>??</td>
<td>S</td>
<td>0:00.05</td>
<td>postgres test [local] DELETE waiting (postmaster)</td>
</tr>
</tbody>
</table>
```

```sql
test=> SELECT * FROM pg_locks;

<table>
<thead>
<tr>
<th>relation</th>
<th>database</th>
<th>transaction</th>
<th>pid</th>
<th>mode</th>
<th>granted</th>
</tr>
</thead>
<tbody>
<tr>
<td>17143</td>
<td>17142</td>
<td></td>
<td>9173</td>
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<td>ExclusiveLock</td>
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</tbody>
</table>
```
Miscellaneous Tasks

- Log file rotation, syslog
- Upgrading
  - `pg_dump`, restore
  - `pg_upgrade`
  - Slony
- Migration
Administration Tools

- pgadmin
- phppgadmin
External Monitoring Tools

- Alerting: check_postgres, tail_n_mail, Nagios
- Server analysis: Munin, Cacti, Zabbix, Nagios, MRTG, Prometheus, Grafana
- Queries: pg_stat_statements, auto_explain, pgbadger
- Commercial: Postgres Enterprise Manager (PEM), Circonus, VividCortex
Monitoring Summary

Operating System: vmstat, iostat

Process/Session: ps, top -c, pg_stat_activity

Query: pg_stat_activity.query, log_statement, log_statement_stats

Parser: log_parser_stats

Planner: log_planner_stats

Executor: log_executor_stats, pg_locks, log_lock_waits, pg_stat_activity.wait_event

Reporting

Alterting / Aggregation

sar, check_postgres, log_temp_files

tail_n_mail

pg_stat_statements, log_min_duration_statement, pgbadger

auto_explain

e.g. pg_stat_all_tables

time
5. Recovery

https://www.flickr.com/photos/coastguardnews/
Nothing Required. Transactions in progress are rolled back.
Nothing Required. Transactions in progress are rolled back.
Nothing Required. Transactions in progress are rolled back.
Operating System Crash

Nothing Required. Transactions in progress are rolled back. Partial page writes are repaired.
Restore from previous backup or use PITR.
Accidental DELETE

Recover table from previous backup, perhaps using pg_restore. It is possible to modify the backend code to make deleted tuples visible, dump out the deleted table and restore the original code. All tuples in the table since the previous vacuum will be visible. It is possible to restrict that so only tuples deleted by a specific transaction are visible.
See pg_resetwal. Review recent transactions and identify any damage, including partially committed transactions.
File Deletion

It may be necessary to create an empty file with the deleted file name so the object can be deleted, and then the object restored from backup.
Accidental DROP TABLE

Restore from previous backup.
Accidental DROP INDEX

Recreate index.
Accidental DROP DATABASE

Restore from previous backup.
Restart problems are usually caused by write-ahead log problems. See `pg_resetwal`. Review recent transactions and identify any damage, including partially committed transactions.
Use REINDEX.
Try reindexing the table. Try identifying the corrupt OID of the row and transfer the valid rows into another table using `SELECT...INTO...WHERE oid != ###`. Use `pageinspect` to analyze the internal structure of the table.
http://momjian.us/presentations