Introduction to Postgres

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Overview

① **Installing Postgres**

② Running Postgres
③ Debugging Postgres
④ Buffer Manager
⑤ Miscellaneous

Source Distribution

- Unpack source tarball:

```
$ cd ~/src/
$ tar -zxvf postgresql-7.2.2.tar.gz
$ export PG_SRC=$HOME/src/postgresql-7.2.2
```

or, if running csh/tcsh:

```
$ setenv PG_SRC $HOME/src/postgresql-7.2.2
```


Source Distribution

- Run configure:

```
$ export PG_BIN=$HOME/pgsql
$ ./configure --prefix=$PG_BIN --with-pgport=$PGPORT
              --enable-depend
              --enable-debug --enable-cassert
              --with-maxbackends=8
```

- Fairly standard process (GNU automake/autoconf).
- Look in `INSTALL` for description of options (or `./configure --help`).

Source Distribution

- Compile and install:

```
$ make
$ make install
```

- You may also want to

```
$ export PATH=$PG_BIN/bin:$PATH
```


Overview

Basic Initialization

- Environment variables

```
$ export PGPORT=nnnnn          # Pre-assigned
$ export PGDATA=$HOME/pgdata
```

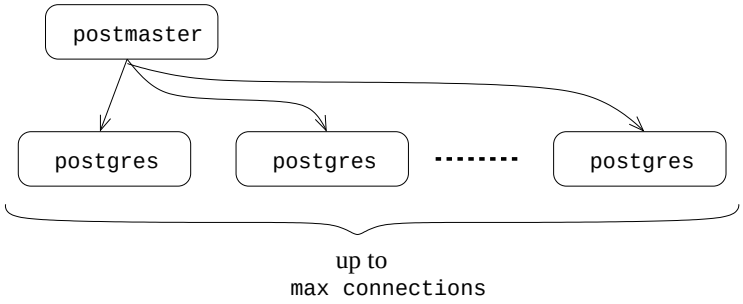
- Database cluster, etc. . .

```
$ initdb

$ pg_ctl start -l $PGDATA/serverlog -o "-i"
$ createdb test
$ pg_ctl stop
```


Postmaster

- Manages multiple client connections
  - Starts one backend process (`postgres`) per client.
- Backends communicate via shared memory.
  - Initialized by `postmaster`.



Bare Backend (Postgres)

```
iluvatar:~$ postgres test
DEBUG:  database system was shut down at 2003-01-23 14:37:33 EST
DEBUG:  checkpoint record is at 0/CF280C
DEBUG:  redo record is at 0/CF280C;
        undo record is at 0/0; shutdown TRUE
DEBUG:  next transaction id: 656; next oid: 186847
DEBUG:  database system is ready

POSTGRES backend interactive interface
$Revision: 1.1.1.1.4.2 $ $Date: 2003/01/18 13:18:41 $

backend> select * from foo;

[...]
```


Basic Options

- Either as command line arguments to `postgres`. . .
- . . . or in `$PGDATA/postgresql.conf`.
- Buffer pool size
  - `pg_ctl start ...  -o "-i -B 16"`
  - `shared_buffers = 16`
  - Must be at least 2×`max_connections`

Basic Options

- Optimizer—disable merge joins:
  - `pg_ctl start ... -o "-i -fm"`
  - `enable_mergejoin = false`
- Optimizer—disable hash joins:
  `-fh` or `enable_hashjoin = false`

Overview

Log Messages

- `elog(DEBUG, ...)`
- Similar to `printf`, but flushes output to the logfile
- Examining log output:

```
$ tail -f $PGDATA/serverlog
ERROR:  zero-length delimited identifier
DEBUG:  pq_recvbuf: unexpected EOF on client connection
DEBUG:  pq_recvbuf: unexpected EOF on client connection
DEBUG:  smart shutdown request
DEBUG:  shutting down
DEBUG:  database system is shut down
```


Log Messages

- You may want to define a preprocessor conditional

```
#define MY_DEBUG_MSGS  /* at top of file */

#ifdef MY_DEBUG_MSGS
elog(DEBUG, ...);
#endif
```

or possibly

```
#define MY_DEBUG_LEVEL 1   /* at top of file */

#if MY_DEBUG_LEVEL > 0
elog(DEBUG, ...);
#endif
```

Assert

- Catch bugs often, catch bugs early!
- `Assert(`*`condition`*`)`
- If condition is false, raises an (uncaught) `FailedAssertion` exception.

GDB / DDD

- Start backend in interactive mode from debugger
- DDD: graphical frontend for GDB
  - Graphical variable displays
  - Or use `print()` and `pprint()` (just for `Nodes`)

```
(gdb) set print elements 0  # no truncation
(gdb) call pprint(nodeptr)
```

BRIEF DEMO

Overview

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④ **Buffer Manager**

⑤ Miscellaneous

Buffer Manager

- *Buffer pool:* A collection of pages in memory.
- *Page:* A fixed-size chunk of storage (default: 8Kb).
  - Fixed-size simplifies management—no external fragmentation.
  - Common approach (e.g., virtual memory vs. overlays).
- In other words: bufferpool is an *array* of pages.
- Also: a parallel array of metadata ("buffer descriptors").
- "Co-operative caching"
  - No traps.
  - Explicit hints by bufferpool users.

Buffer Manager

- Pin
  - "Get me a page (if not there already)"
  - "I will be using it"
  - Pin count = counter of page "users"
- Unpin
  - "I'm done using the page"
  - "I (have / haven't) modified it"
  - If pin count = 0, page can be evicted.
  - If modified, must first be written to disk.

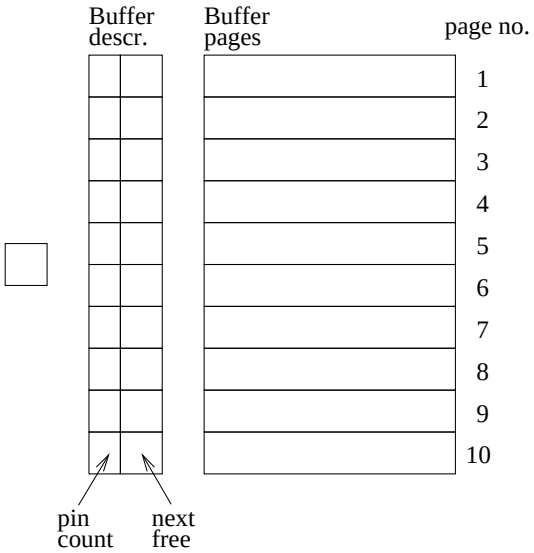
Replacement Policies

- When there are many unpinned pages, how do we select the one to evict?
- Random
- Least Recently Used (LRU)
- Most Recently Used (MRU)
- First-In First-Out (FIFO)
- Clock

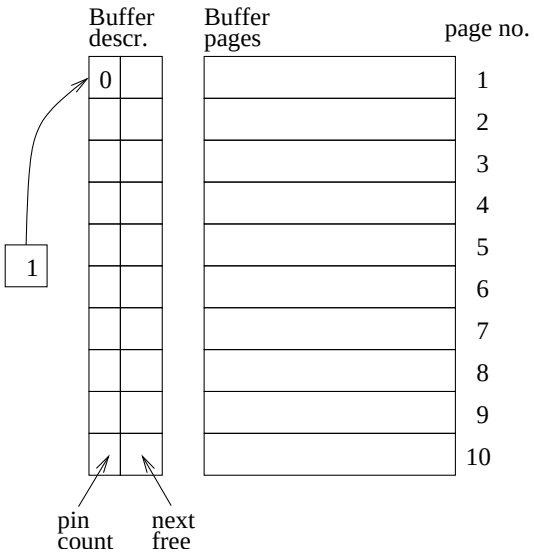
Replacement Policies—LRU

- Select least recently used page
- Used = ??
- Unpin = "I'm done using the page"
- When pin count becomes 0. . .
- Enqueue page
- Queue order = Last used order
- Victim = dequeue
- Queue implemented as a linked list (*freelist*)

Replacement Policies—LRU



Replacement Policies—LRU



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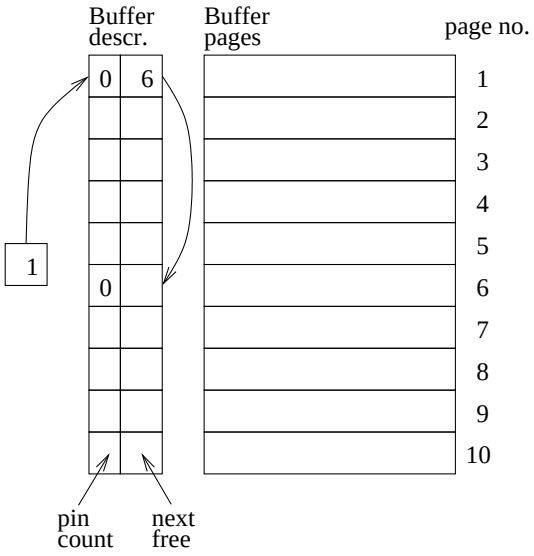

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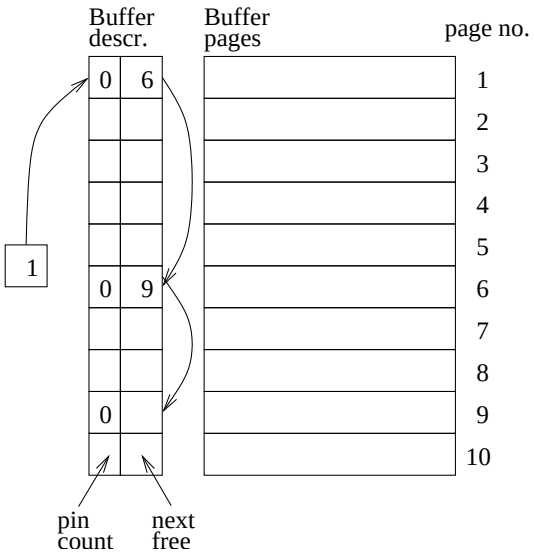
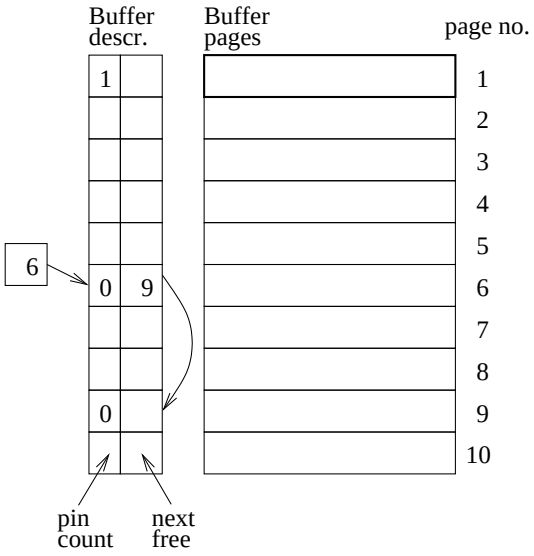


Replacement Policies—LRU



Replacement Policies—MRU

- *Most* recently used page
- What changes?
- Stack instead of queue
- Why?
  - Consider repeated sequential scan of $N+1$ pages (N buffers). . .

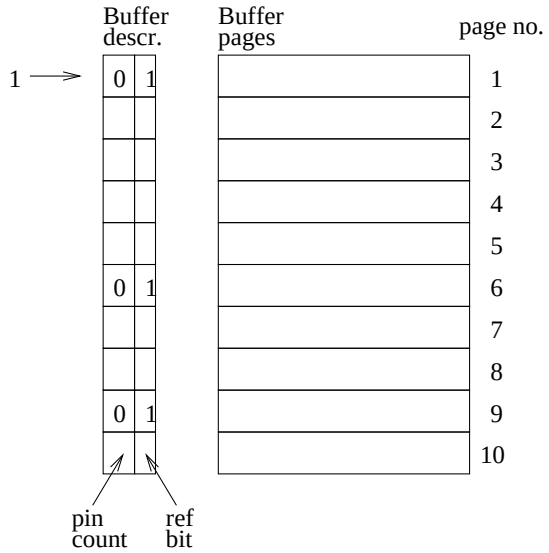
Replacement Policies—FIFO

- Least recently *brought in* page
- What changes?
- Queue again, but enqueue when pinning (not unpinning)
- Aside: Belady's anomaly (more buffers, more misses).

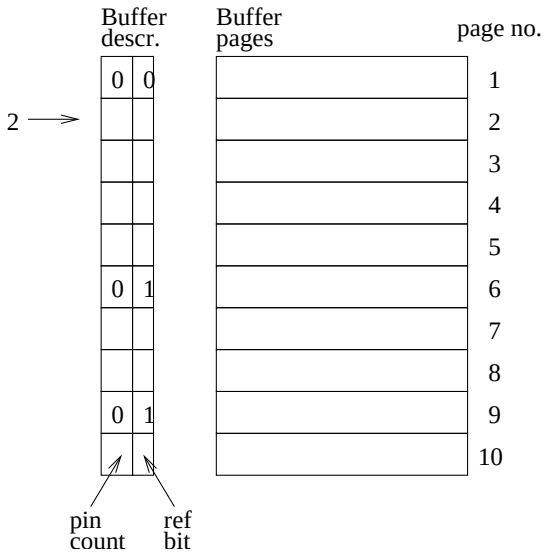
Replacement Policies—Clock

- Round-robin with a twist. . .
- Less space overhead
- Do not maintain complete order (freelist)
- Keep a "referenced" bit per page (set on last unpin)
- Visit *all* pages in bufferpool (round-robin):
  - If pinned, don't touch it
  - If unpinned and referenced, unset referenced bit
  - If unpinned and not referenced, select as victim
- Sometimes called "second chance"

Replacement Policies—Clock



Replacement Policies—Clock



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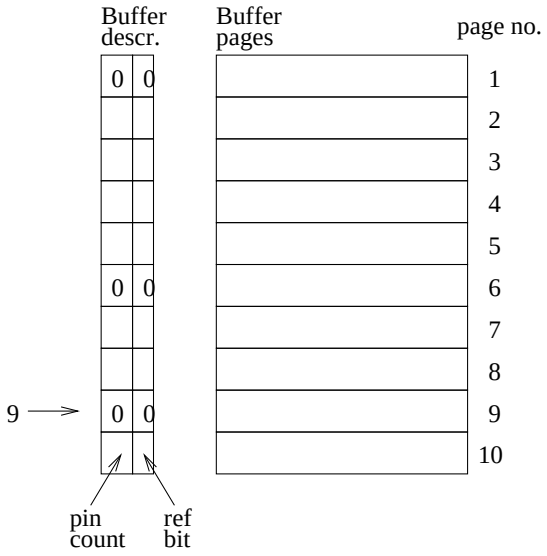
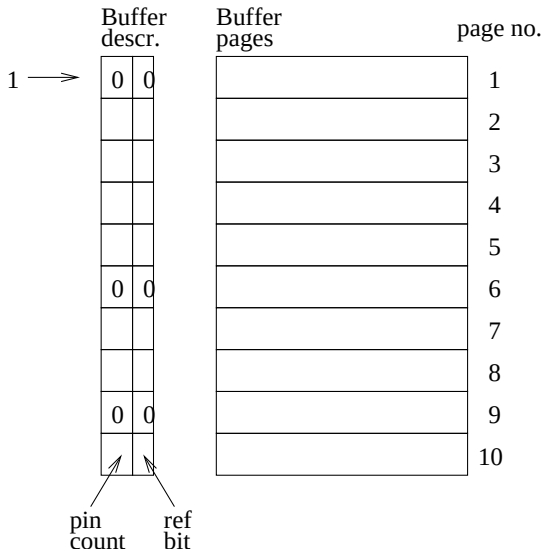
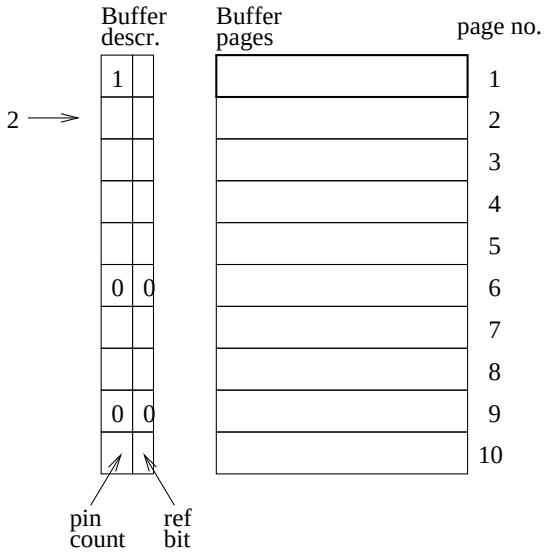


Replacement Policies—Clock



Replacement Policies—Clock



Replacement Policies—Clock

- Consider:
  - Instead of a flag ("referenced")
  - A counter ("timestamp")
    - Incremented on every last unpin
    - Decremented
    - Victim if "timestamp" = 0
- This is LRU; in Clock the timestamp is reduced to 1 bit.

Overview

C Trivia

Q. What does the following code do?

```
MASK_FREE = 2;
flags |= MASK_FREE;
```

A. Sets second bit of `flags`.

C Trivia

Q. How do you clear the second bit?

A.

```
flags &= ~MASK_FREE;
```

C Trivia

Q. What is wrong with the following code?

```
typedef struct node_t {
   int *data;
   struct node_t *next;
} node_t;
node_t *p;
...
/* p != NULL */
do {
   p = p->next;
   if (p->data == NULL)
      continue;
} while (*p->data < 5);
```


C Trivia

Q. What is wrong with the following code?

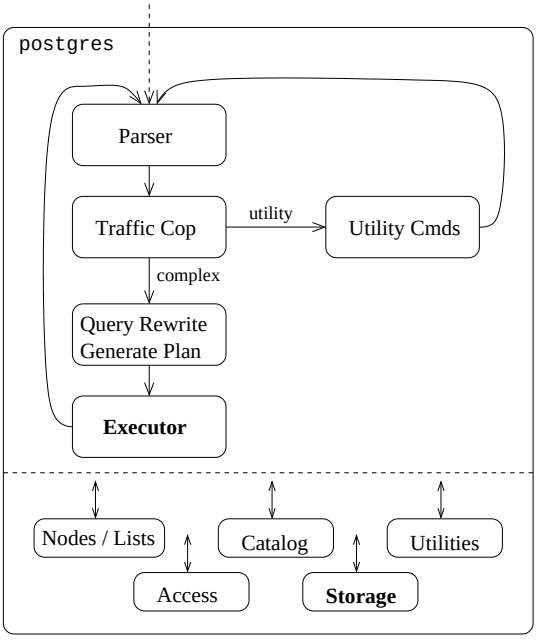
```
typedef struct node_t {
   int *data;
   struct node_t *next;
} node_t;
node_t *p;
...
/* p != NULL */
do {
   p = p->next;
   if (p == NULL)
      break;
   if (p->data == NULL)
      continue;
} while (*p->data < 5);
```

C Trivia

A. Careful about `continue` semantics: termination condition is evaluated. Use `goto` if you *absolutely* have to.

```
typedef struct node_t {
   int *data;
   struct node_t *next;
} node_t;
node_t *p;
...
/* p != NULL */
do {
   p = p->next;
   if (p == NULL)
      break;
} while (p->data == NULL || *p->data < 5);
```


Preview



Assignments:

1. Buffer manager (storage)
2. Query executor