Physical storage in DBMS

Chapter content:

- Storage : DBMS adapts to hardware (Reminder)
- Reads vs Writes: storage architectures
- Techniques for handling updates
- Physical storage in RDBMS

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New DB technologies and trends

Data storage and processing evolutions:

- New hardware (FPGA, GPGPU, SSD, NVRAM)
- In-memory DB/ Column storage
- NoSQL: (shared nothing) massively parallel architecture (Map/Reduce, key/value)

Trends emphasize

- supporting both *analytical* (OLAP, mining) and *prediction* queries (statistical ML)
- ACID in distributed data processing
- trust management – so far, more of an issue for transactions rather than storage/analysis (blockchain)
- integrating new (external) types of data (text, feeds, images, video...)
- building data summaries (data too large to be stored): sampling, etc.
- real-time DW

Hardware: data storage

The hard drive

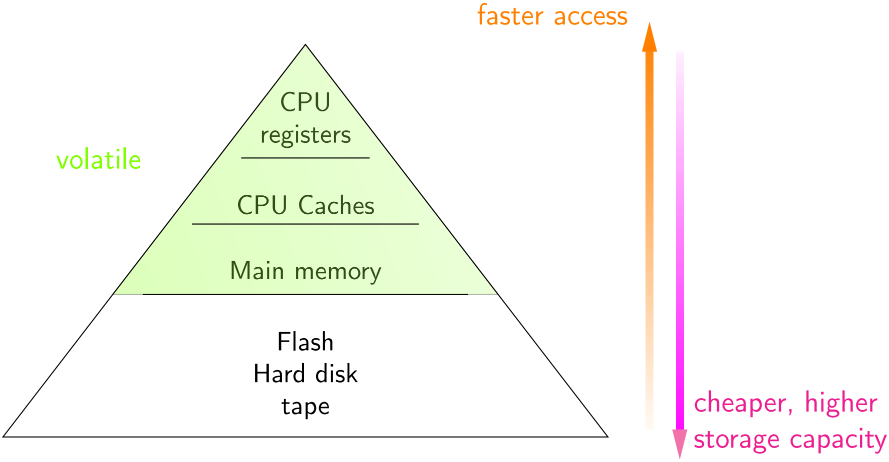
Created in 1956 (IBM).
Multiple disks (platters) spinning rapidly together (thousands rpm/min).
Ferromagnetic. Multiple tracks per platter. 1 head per platter, on air cushion.

$\approx$ 100€
a few TB
100gr.

Main storage device (secondary storage) since 1960.
The support for which DBMS were devised.

Hardware: storage

Memory hierarchy:



On early computers, CPU frequency $\approxeq$ memory bus and memory access.
But CPU became much faster than memory.

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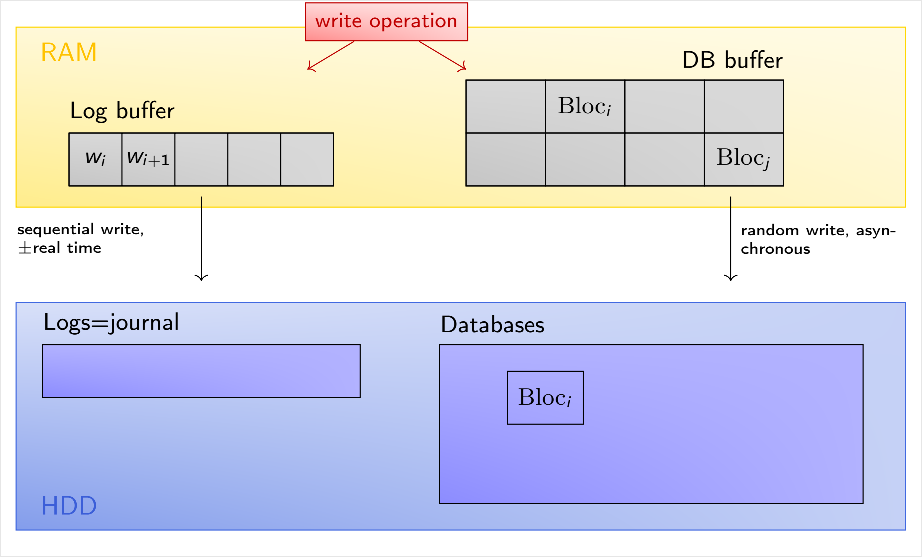
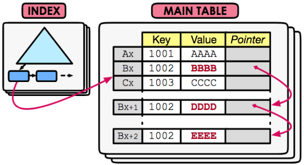
Physical storage in DBMS

Handling writes in DBMS

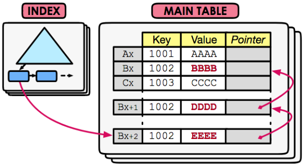


Architecture types (MVCC) in terms of tables

O2N : oldest-to-newest
N2O : newest-to-oldest

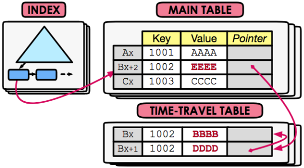


(a) Append-only (O2N)



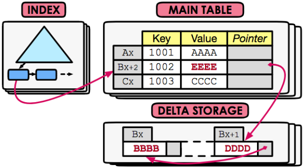
(b) Append-only (N2O)

NUODB



(c) Time-travel Storage

SAP



(d) Delta Storage

ORACLE MariaDB

http://www.vldb.org/pvldb/vol10/p781-Wu.pdf (VLDB'17)

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How storage architectures deal with updates

- *update-in-place* storage: most relational DB. Limitations: versioning (SCD 2) results in fragmentation. Lock on page during update.
  Strategy often used with B-tree index. Provides optimal reads (≊1 seek per read/1 per scan if unfragmented). But updating index slower.

- *log-structured* storage: all updates appended as a log (no "main").
  Limitations: scans get expensive: must read all logs. But writes faster than in B-tree (and no lock).
  A popular version: *LSM-tree* (Log-Structured Merge tree).
- *delta* with main store: main store is read-optimized, updates recorded in write-optimized buffer *(SAP Hana/Sans Souci, and other column stores)*. Buffer merged from time to time.

↪ **Rationale for log-structured storage: instead of writing a full page on each update, defer and process them in batch. Idea of *deferred writes* common with delta approach.**

LSM-tree

Storage optimized for write-throughput (as every log-structured storage):

- LSM-tree consists of 2 or more layers $C_0, C_1(, C_2 \ldots, C_k)$.
- C_0 in-memory, can be tree, hash table...
- others $(C_1, \ldots)$ are B-trees, recorded on disk/slower memory.
- updates written only in C_0
- $\forall i$ when C_i is full, we merge it into C_{i+1} (C_i is emptied)
  $\hookrightarrow$ $\forall i$ versions in C_i always more recent than in C_{i+1}
  $\hookrightarrow$ at most r versions of record co-exist.
  $\hookrightarrow$ a Read must search layers $C_0, C_1 \ldots$ until item found.

...but we did not detail what "full" means:

Original version: [O'Neill et al. 1996]

- recommend using geometric progression: $|C_{i+1}| = r \times |C_i|$
  $\hookrightarrow$ total number of unique keys: $N = O(r^k)$.
- but claimed inefficient (does not exploit write locality)

LSM-tree: assets and drawbacks (compared to Btree)

Buffered writes makes writes faster.

Pros:

- ✔ write operations are faster (sequential)
- ✔ lower fragmentation (so range queries get more efficient)

Weaknessess:

- ✘ accessing a given value may be slow

cassandra mongoDB APACHE HBASE SQLite LEVELDB

References

Rappels simples sur le stockage dans les SGBDs

- *http://sys.bdpedia.fr/*

MVCC storage

- *http://www.vldb.org/pvldb/vol10/p781-Wu.pdf*

LSM trees

- *http://www.vldb.org/pvldb/vol10/p1526-bocksrocker.pdf*
- *http://www.eecs.harvard.edu/~margo/cs165/papers/gp-lsm.pdf*
- *https://www.quora.com/How-does-the-Log-Structured-Merge-Tree-work*

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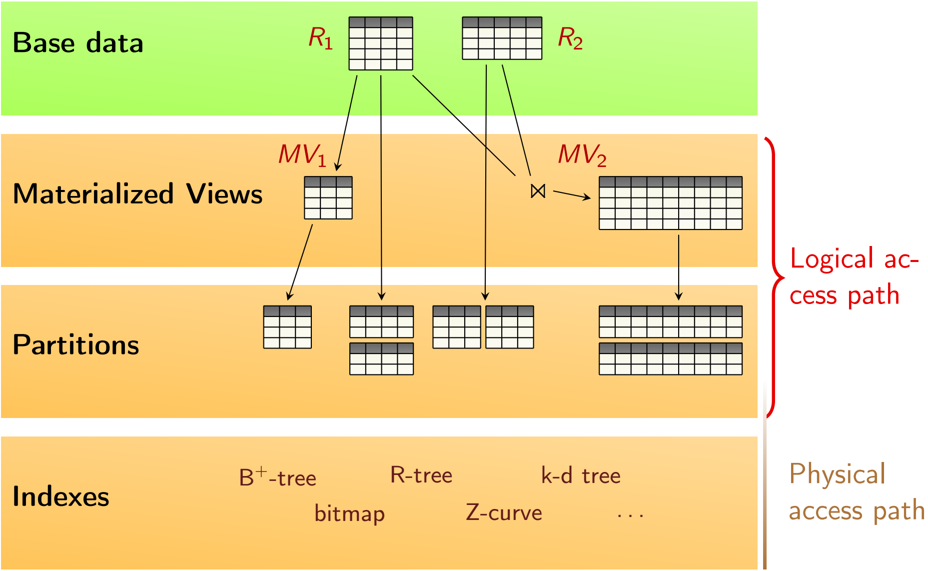
3 levels of design

Conceptual design	User-oriented description, independant of implementation *E-R, UML*
Logical design	Logical description, independant of DBMS *Relational model: table schema*
Physical design	Actual database structures *materialized views, partitions, indexes*

Accessing data



: logical schema (ANSI SPARC architecture)

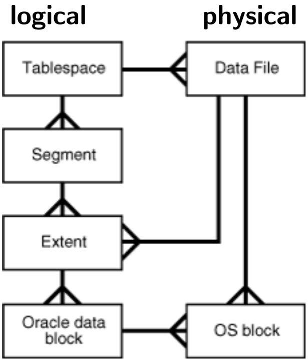
: physical schema (ANSI SPARC architecture)

Physical storage in DBMS (reminder)

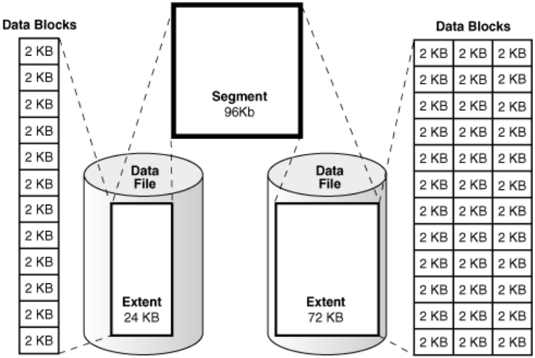
- physical address of record provided by ROWID
- Records stored in pages=blocks.
- Read/Write operations require the corresponding data be brought in buffer (main memory).
- DBMS must minimize pages I/O for performance.

larger block size: more tuples edited per page I/O, but fewer pages in main-memory.

Physical storage: Oracle (1)



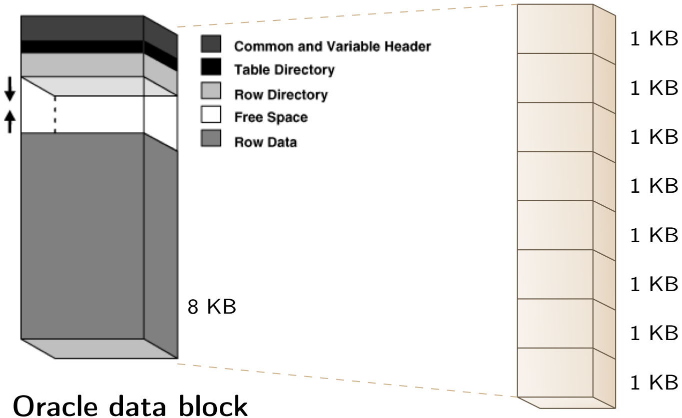
E-R diagram of storage structures



logical storage

[*Oracle Database Concepts*]

Physical storage: Oracle (2)



Oracle data block

O.S. blocks

References

Oracle Database Concepts
https://docs.oracle.com/database/121/CNCPT/logical.htm

https://en.wikibooks.org/wiki/Oracle_and_DB2,_Comparison_and_Compatibility/Storage_Model/Physical_Storage/Summary

ftp://ftp.software.ibm.com/software/data/db2/9/labchats/20110331-slides.pdf
(a bit outdated: 2011...)

http://www.postgresql.org/docs/9.4/static/storage-page-layout.html