

LevelDB Study

Introduction 2

2022. 07. 05

Presented by Min-guk Choi

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Previous Homework

- SSH

- Linux
 - Server
 - VM
- Window
 - Putty
 - Xshell
 - VS code

- VS code Extension

- Remote Development
 - <https://marketplace.visualstudio.com/items?itemName=ms-vscode-remote.vscode-remote-extensionpack>
- C/C++ Extension Pack
 - <https://marketplace.visualstudio.com/items?itemName=ms-vscode.cpptools-extension-pack>
- More Extension...
 - <https://lazyren.github.io/devlog/recommended-vscode-extension-list.html> (KOR)
 - <https://jhnyang.tistory.com/409> (KOR)

Github Watch/Star

The screenshot shows the GitHub interface for the repository **DKU-StarLab / leveldb-study** (Public). The repository has 16 watchers and 18 stars. A notifications dropdown menu is open, showing three options: **Participating and @mentions**, **All Activity** (which is selected with a checkmark), and **Ignore**. A **Custom** option with a right arrow is also visible at the bottom of the dropdown. The repository's file list includes folders for **analysis**, **implementation**, **introduction**, and **photo**, each with associated updates or actions listed next to them.

| File/Folder | Action/Update |
|----------------|-----------------------|
| analysis | Create README.md |
| implementation | poster & photo update |
| introduction | week2 ppt update |
| photo | poster & photo update |

Github Issue

DKU-StarLab /
leveldb-study Public

Edit Pins Unwatch 16 Fork 0 Starred 18

Code Issues 3 Pull requests Actions Projects Wiki Security Insights ...

Team Selection #3

Edit

New issue

Open

korea-choi opened this issue 4 days ago · 4 comments



korea-choi commented 4 days ago

Member



How's it going?

Assignees



No one—assign yourself

Labels



1. LevelDB Architecture
2. Key-Value Interface
3. Internal Operations
4. Data Structure
5. LevelDB Installation
6. db_bench experiment
7. References
8. Homework

- LevelDB Architecture
 - ✓ LSM-tree
 - Log-structured, Merge, Tree
 - ✓ LevelDB Implementation
 - Memtable, WAL, SSTable

LSM-tree

- What is LSM-tree
 - By Patrick O'Neil, The Log-Structured Merge Tree, 1996
 - Write optimized data structure
 - Log-structure
 - In-place update
 - ✓ good for read, bad for write
 - ✓ due to random writes
 - Out-of-place update
 - ✓ good for write, possible bad for read
 - ✓ due to multiple locations
 - ✓ need reclaiming mechanism

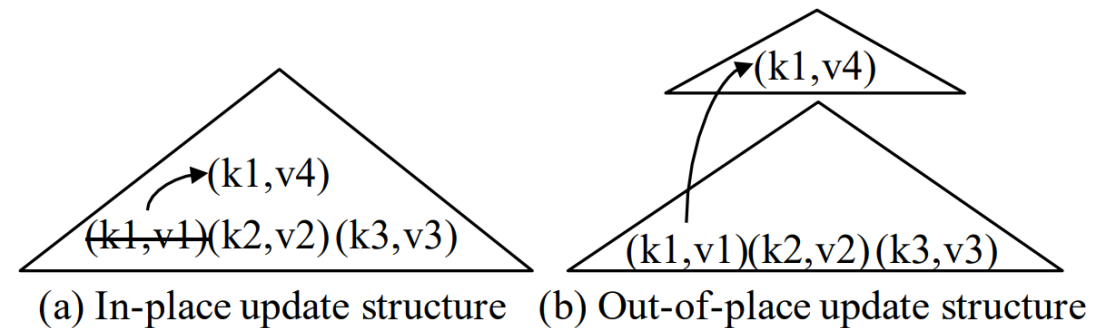


Fig. 1: Examples of in-place and out-of-place update structures: each entry contains a key (denoted as “k”) and a value (denoted as “v”)

(LSM-based Storage Techniques, VLDB Journal'19)

LSM-tree

- What is LSM-tree
 - Tree
 - larger at lower levels like a tree
 - C_0 is in main memory while $C_1 \sim C_K$ in Storage

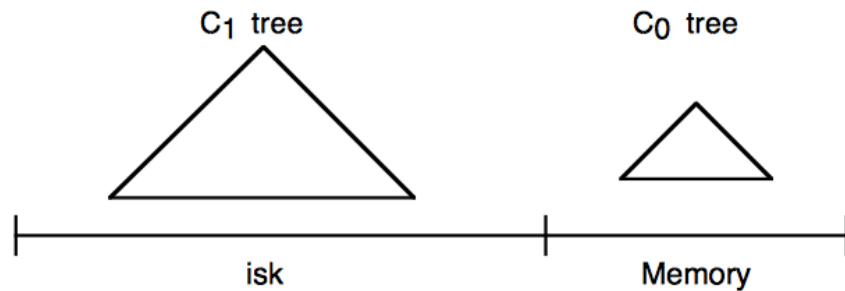


Figure 2.1. Schematic picture of an LSM-tree of two components

(Patrick O'Neil, The Log-Structured Merge Tree, 1996)

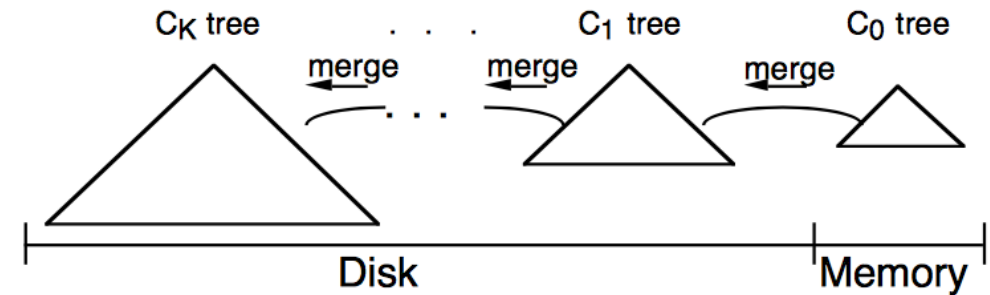
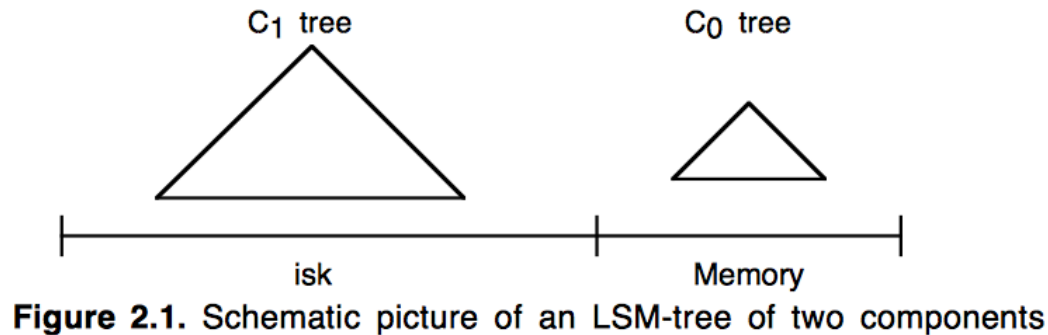


Figure 3.1. An LSM-tree of $K+1$ components

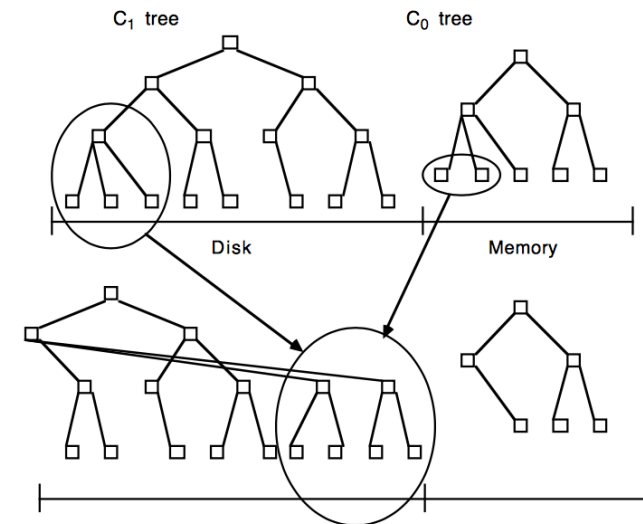
(Patrick O'Neil, The Log-Structured Merge Tree, 1996)

LSM-tree

- What is LSM-tree
 - Rolling Merge
 - Merge sort levels onto subsequent levels for deleting old data
 - All data in sorted order



(Patrick O'Neil, The Log-Structured Merge Tree, 1996)



(Patrick O'Neil, The Log-Structured Merge Tree, 1996)

Architecture

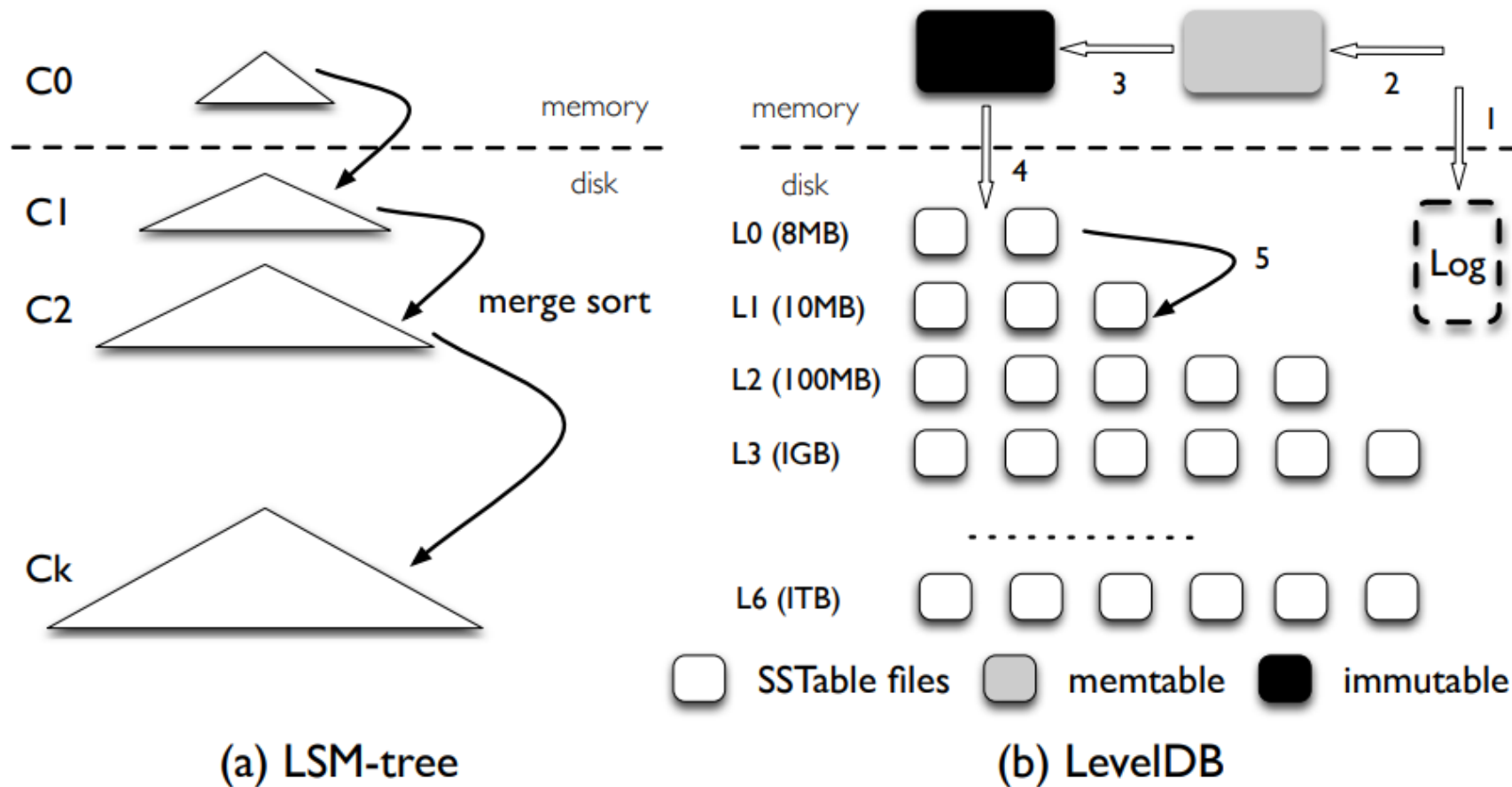


Figure 1: **LSM-tree and LevelDB Architecture.** *This*

Lanyue Lu, WiscKey (Fast '16)

Architecture

- Real implementation in LevelDB
 - Memtable for C0
 - Further separated into mutable and immutable
 - Managed by the Skiplist data structure (or hash)
 - A set of SSTables for C1~Ck (multiple Levels, configurable)
 - Default fanout ratio = 10, $|L_{i+1}| / |L_i|$
 - SSTable internals
 - ✓ data block, index block (logically B+-tree)
- Log (WAL) for durability
 - A set of records where each record consists of CRC, size, type and payload

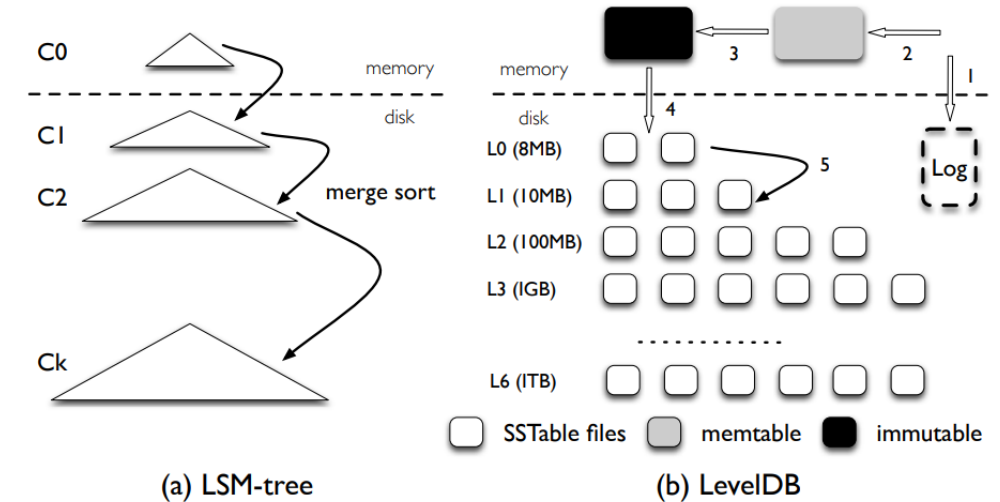


Figure 1: **LSM-tree and LevelDB Architecture.**

Lanyue Lu, WiscKey (Fast '16)

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- Key-Value Interface / Operations
 - ✓ Key-Value Interface
 - Put/Delete
 - Get
 - Range Scan (Seek)

Key-Value Interface

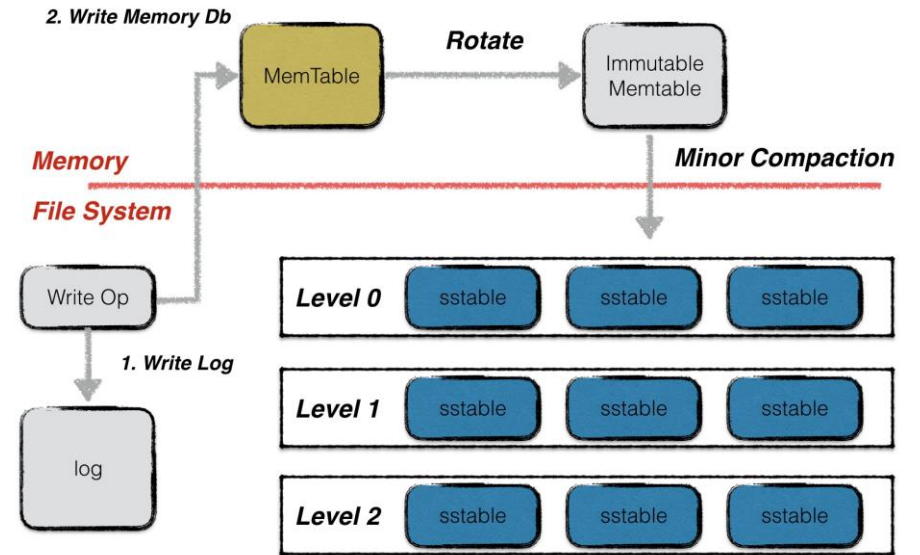
- Key/Value: Arbitrary byte streams
- User visible interfaces
 - put, get, range scan(iterator), delete, single delete, ...

```
std::string value;  
leveldb::Status s = db->Get(leveldb::ReadOptions(), key1, &value);  
if (s.ok()) s = db->Put(leveldb::WriteOptions(), key2, value);  
if (s.ok()) s = db->Delete(leveldb::WriteOptions(), key1);
```

```
leveldb::Iterator* it = db->NewIterator(leveldb::ReadOptions());  
for (it->SeekToFirst(); it->Valid(); it->Next()) {  
    cout << it->key().ToString() << ": " << it->value().ToString() << endl;  
}  
assert(it->status().ok()); // Check for any errors found during the scan  
delete it;
```

Put/Delete

- Put
 - Insert into memtable
 - Batch write
- Delete
 - Insert a delete marker to the memtable
 - annihilates with the value during compaction.



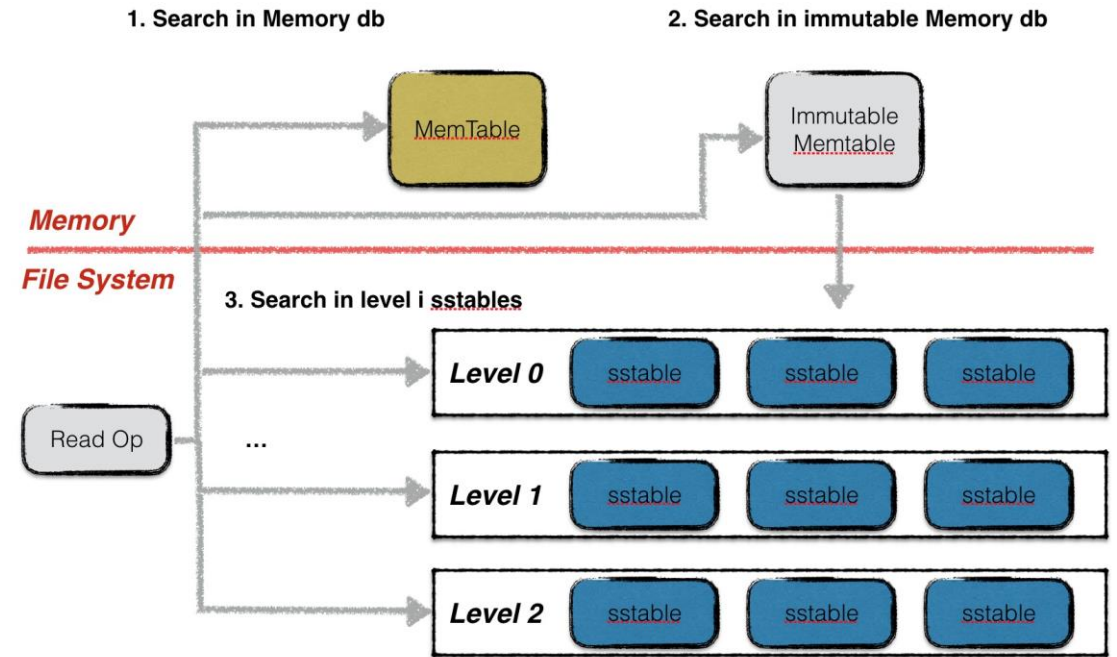
<https://leveldb-handbook.readthedocs.io/zh/latest/>

| | | | | |
|----------------------------|-------------------|---------|-------|---------|
| SequenseNumber (uint64) | count (uint32) | record0 | | recordN |
|----------------------------|-------------------|---------|-------|---------|

| | | | | |
|---------------------|-----------------------|-----------------------|-------------------------|---------------------------|
| ValueType (char) | key_len (varint32) | key_data (key_len) | value_len (varint32) | value_data (value_len) |
|---------------------|-----------------------|-----------------------|-------------------------|---------------------------|

Get

1. Memtable
2. Immutable Memtable
3. SSTables
 - Bloom filter
 - Cache



<https://leveldb-handbook.readthedocs.io/zh/latest/>

Range Scan (Seek)

1. (Merge) Iterator

- Memtable
- Immutable Memtable
- SSTable in each levels

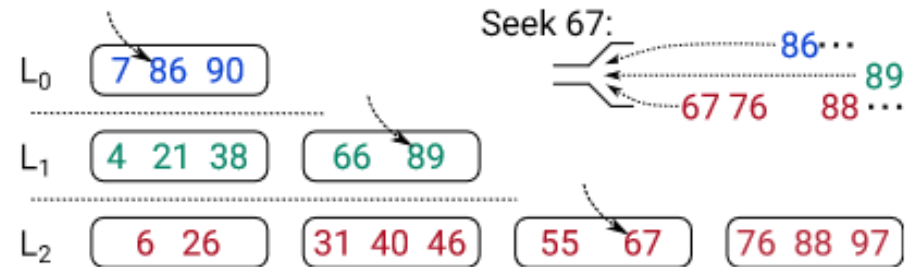
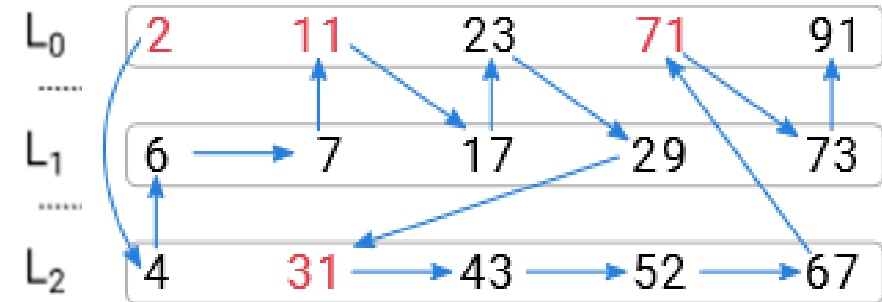


Figure 1: An LSM-tree using leveled compaction

Wenshao Zhong, REMIX: Efficient Range Query for LSM-trees, FAST '21

2. Iterate until done



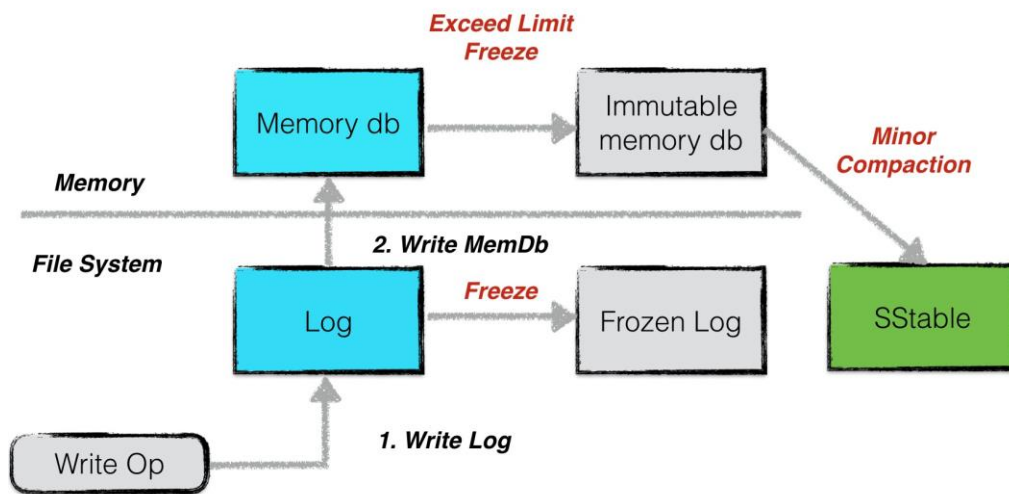
Wenshao Zhong, REMIX: Efficient Range Query for LSM-trees, FAST '21

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- Key-Value Interface / Operations
 - ✓ Internal Operations
 - WAL
 - Flush
 - Compaction

WAL

- Write Ahead Log

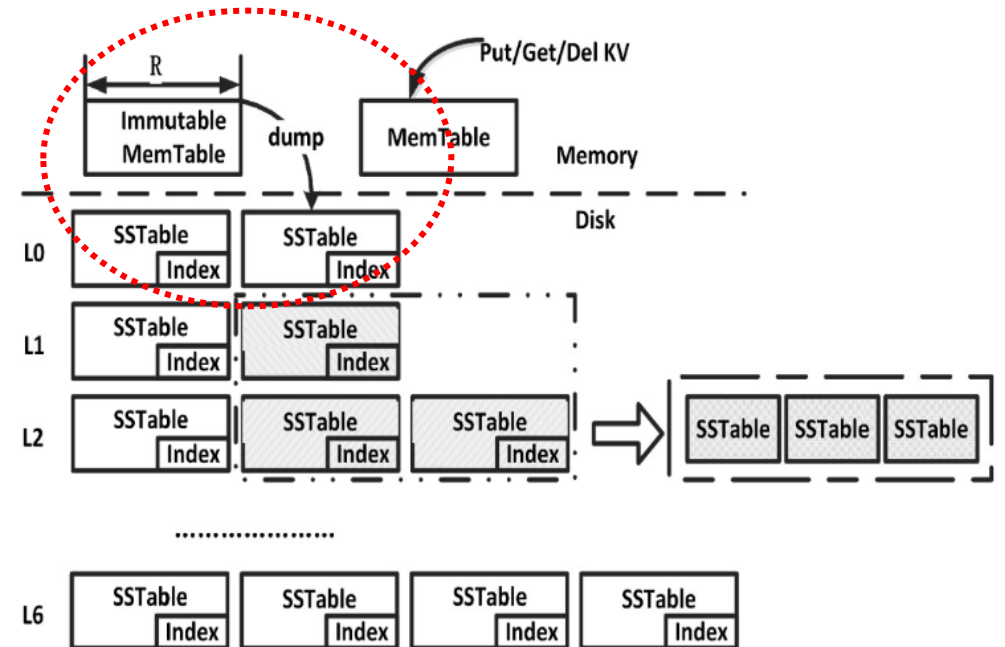


<https://leveldb-handbook.readthedocs.io/zh/latest/>

```
-rw-r--r-- 1 root root 37922501 7월 1 15:44 000214.sst
-rw-r--r-- 1 root root 37920200 7월 1 15:44 000216.sst
-rw-r--r-- 1 root root 37910828 7월 1 15:44 000219.sst
-rw-r--r-- 1 root root 37906740 7월 1 15:44 000221.sst
-rw-r--r-- 1 root root 37905482 7월 1 15:44 000224.sst
-rw-r--r-- 1 root root 37909294 7월 1 15:44 000227.sst
-rw-r--r-- 1 root root 66217640 7월 1 15:44 000228.log
-rw-r--r-- 1 root root 37892964 7월 1 15:44 000229.sst
-rw-r--r-- 1 root root 18621323 7월 1 15:44 000231.log
-rw-r--r-- 1 root root 16 7월 1 15:43 CURRENT
-rw-r--r-- 1 root root 37 7월 1 15:43 IDENTITY
-rw-r--r-- 1 root root 0 7월 1 15:43 LOCK
-rw-r--r-- 1 root root 572956 7월 1 15:44 LOG
-rw-r--r-- 1 root root 14592 7월 1 15:44 MANIFEST-000004
-rw-r--r-- 1 root root 6180 7월 1 15:43 OPTIONS-000007
```

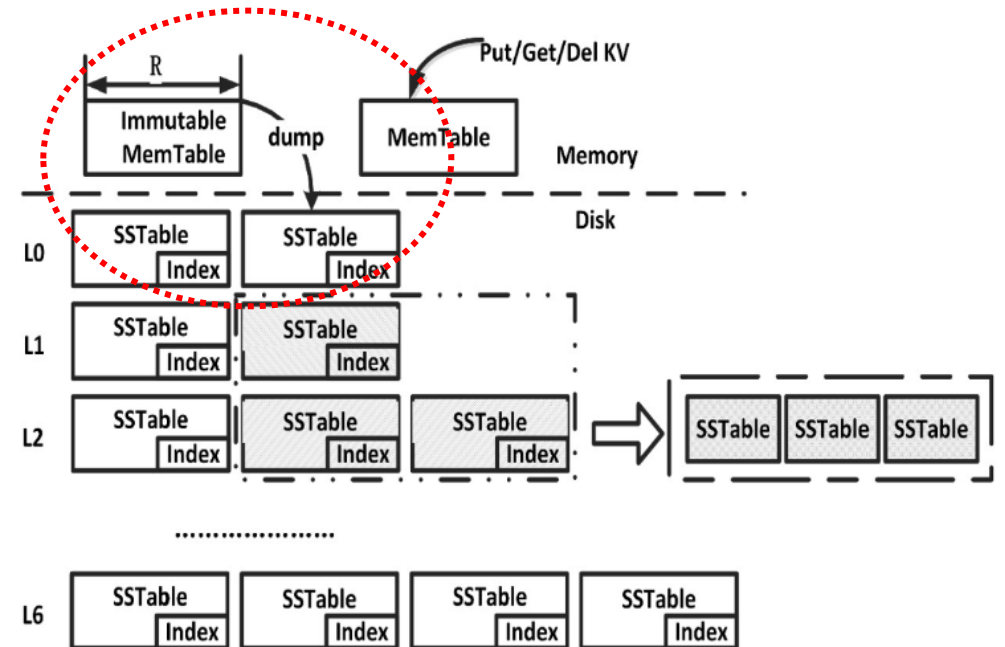
Flush

- Flush
 - Dump immutable into SST file
 - Trivial Move
 - Push as further down as possible if
 - ✓ No overlap with current level
 - ✓ Overlapping with no more than 10 SSTs in the next level



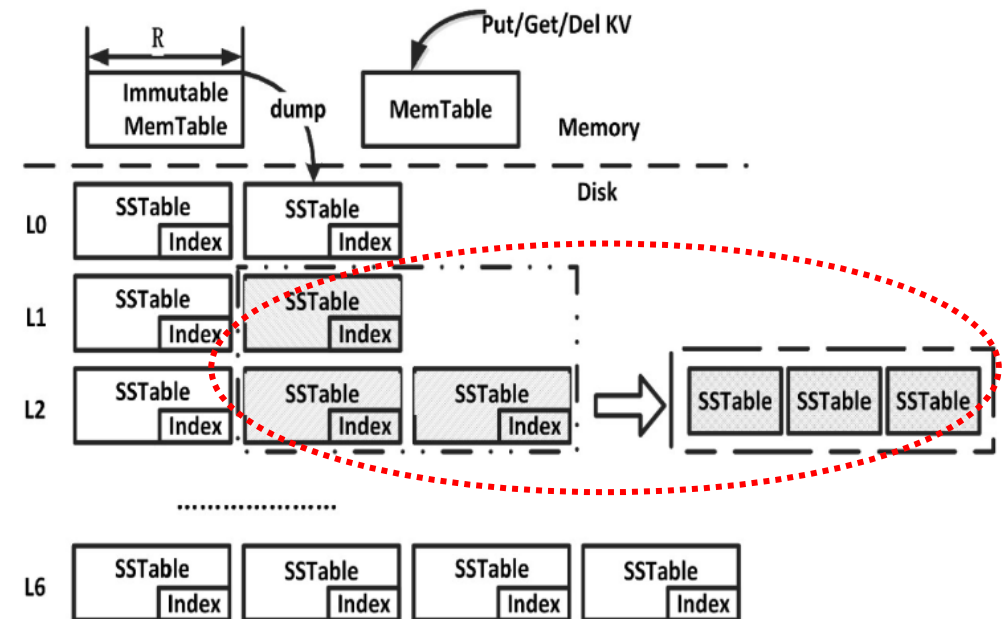
Flush

- Trigger (both must be satisfied)
 - memtable exceeds 4MB
 - immutable = NULL
- Procedure
 - Block write thread
 - move memtable to immutable
 - create new memtable.
 - Background flushing for immutable



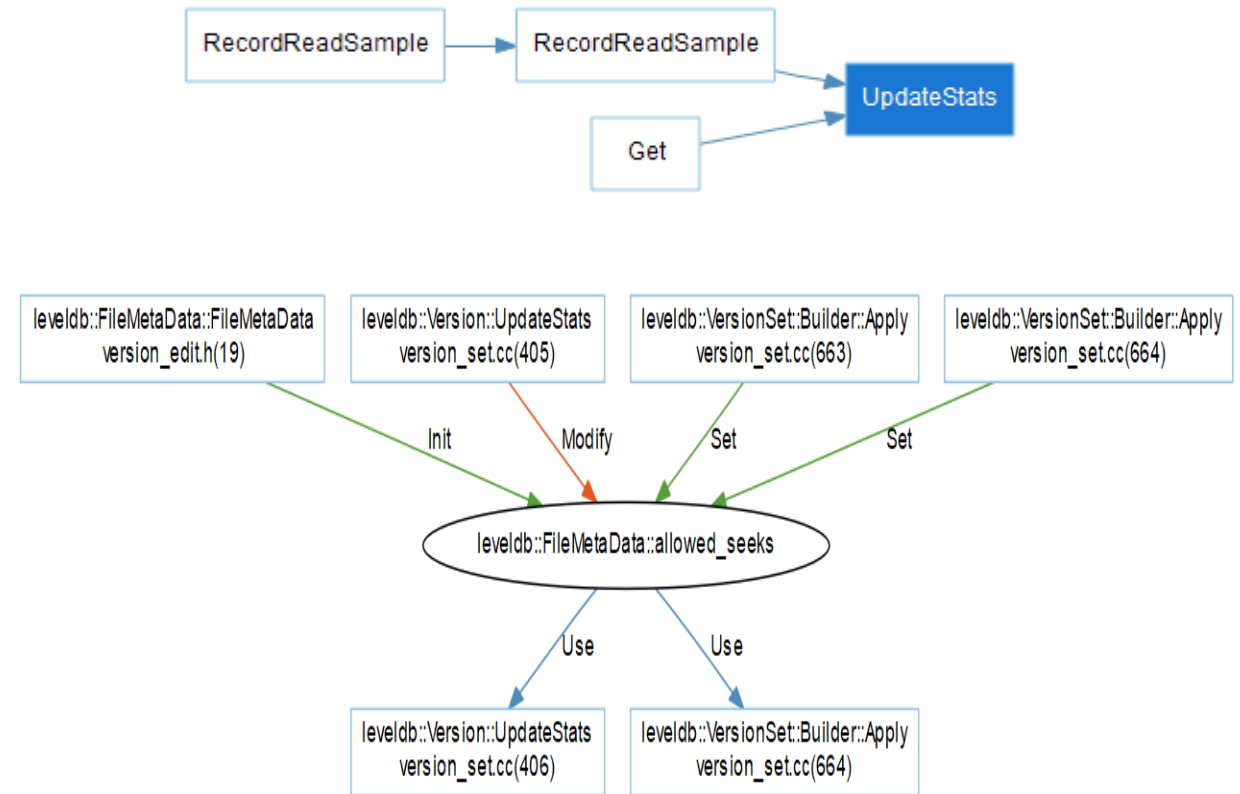
Compaction

- Trigger (at least one of the conditions listed is satisfied)
 - L0 SST exceeds 8
 - L_i ($i > 0$) SST space exceeds 10^i MB
 - allowed_seek used up when calling Get() (RAF)
 - Manual Compaction
- Check During
 - DB open, Write, Get, Compaction



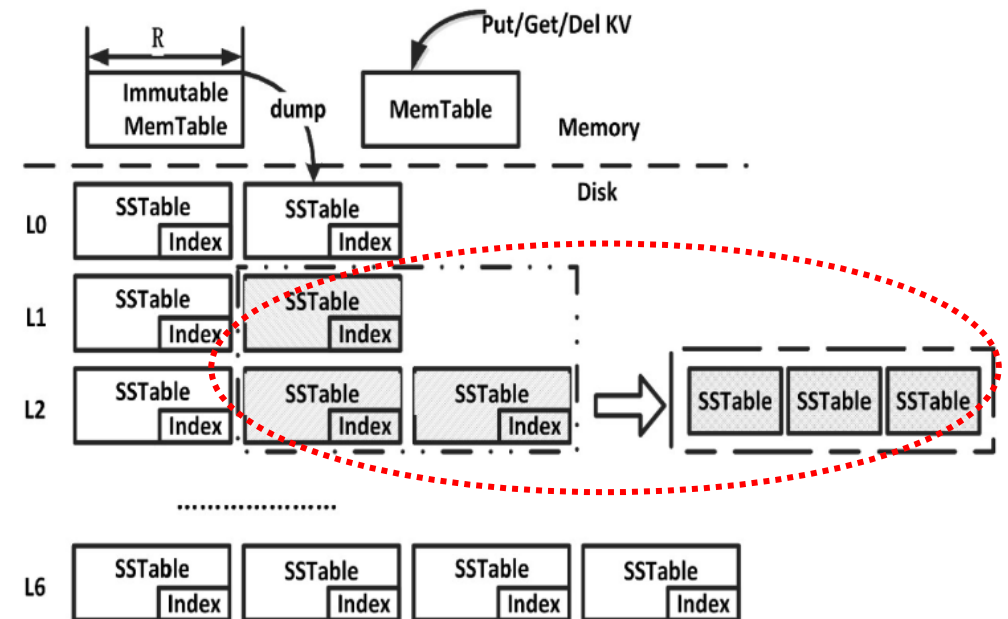
Compaction

- Trigger (at least one of the conditions listed is satisfied)
 - L0 SST exceeds 8MB
 - L_i ($i > 0$) SST space exceeds 10^i MB
 - allowed_seek used up when calling Get() (RAF)
 - Manual Compaction
- Check During
 - DB open, Write, Get, Compaction



Compaction

- Procedure
 - MaybeScheduleCompaction
 - BackgroundWork
 - PickCompaction
 - Pick level and SST
 - Pick same level's overlapped SSTs
 - Pick next level's overlapped SSTs
 - DoCompaction
 - Merge Iterator
 - ✓ merge sort, garbage collection
 - Write new SSTs (max file size)



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- Data Structure

- ✓ Slice, Key
- ✓ Log
- ✓ Memtable
- ✓ SSTable
- ✓ Bloom Filter
- ✓ Cache
- ✓ Manifest

Slice

- `leveldb::Slice`
 - return value of `it->key()`, `it->value()`
- a simple structure that contains a length and a pointer to an external byte array.
- Slice is cheaper than `std::string`
 - not need to copy potentially large keys and values.
- Does not return null-terminated C-style strings
 - leveldb keys and values are allowed to contain `'\0'` bytes.

```
class Slice {  
    ...  
    private:  
    const char* data_;  
    size_t size_;  
};
```


Key

- Value Type
 - Value, Deletion
- Sequence Number
 - every put/delete operation has a sequence number
 - 64bits global variable
 - compaction, snapshot depends on the sequence number.
- Key
 - userkey: passed from user, in Slice format
 - InternalParsedKey: userkey + seqNum + valuetype
 - InternalKey: string representation of InternalParsedKey

```
enum ValueType {  
    kTypeDeletion = 0x0,  
    kTypeValue = 0x1  
};
```

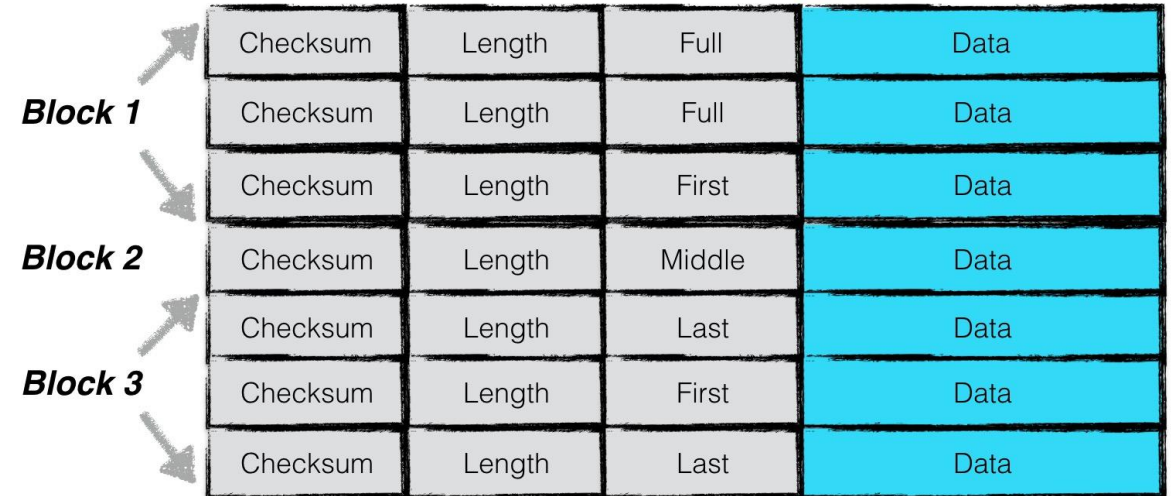
```
// Returns the user key portion of an internal key.  
inline Slice ExtractUserKey(const Slice& internal_key) {  
    assert(internal_key.size() >= 8);  
    return Slice(internal_key.data(), internal_key.size() - 8);  
}
```

```
struct ParsedInternalKey {  
    Slice user_key;  
    SequenceNumber sequence;  
    ValueType type;
```

```
// Three-way comparison. Returns value:  
//  < 0 iff "*this" < "b",  
//  == 0 iff "*this" == "b",  
//  > 0 iff "*this" > "b"  
int compare(const Slice& b) const;
```

Log

- File
 - *.log: WAL file
 - LOG: not a WAL file, text info log
- Block (32KB)
 - Sequence of chunks
- Chunk header
 - checksum (4B), len(2B), type(1B),
 - Types of chunk
 - Full / First / Middle / Last

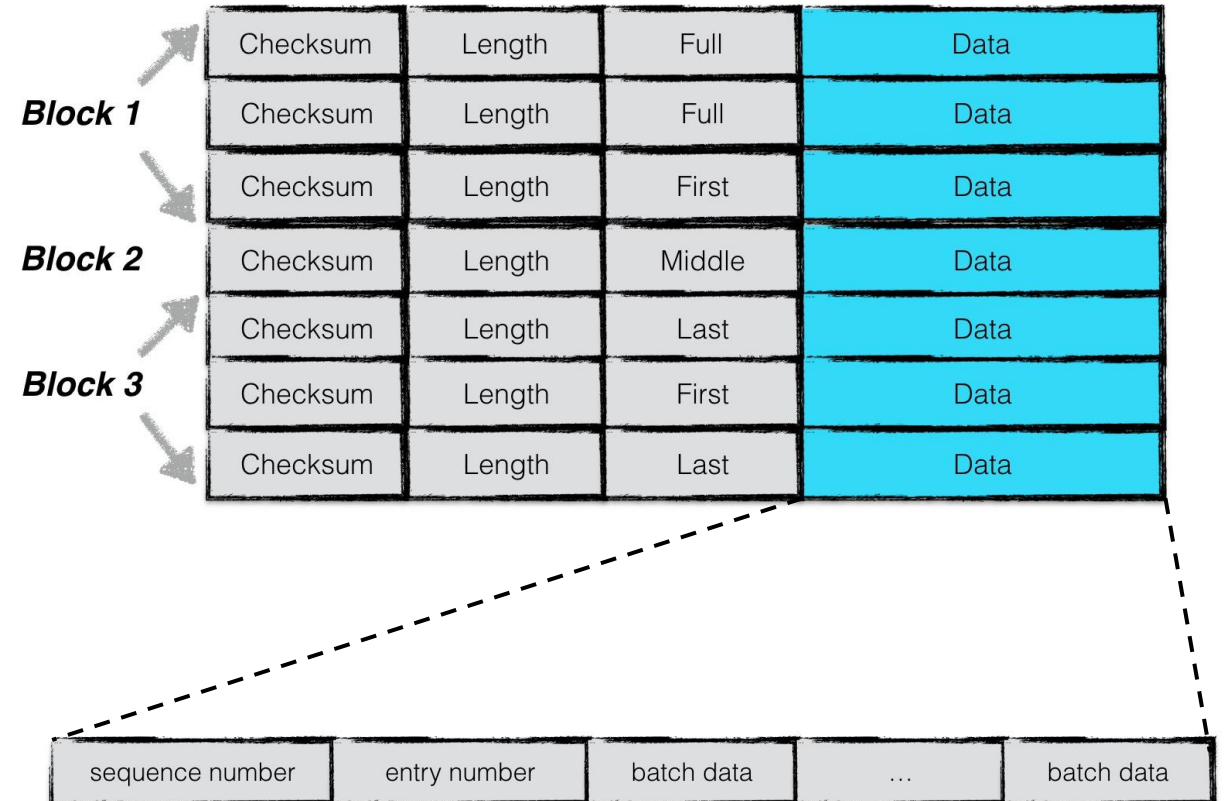


<https://leveldb-handbook.readthedocs.io/zh/latest/>

```
mingu@sever: /tmp/leveldbtest-1000/dbbench$ cat LOG
2022/07/06-15:01:31.954351 139755705333568 Creating DB /tmp/leveldbtest-1000/
2022/07/06-15:01:31.969198 139755705333568 Delete type=3 #1
2022/07/06-15:01:32.016174 139755618563840 Level-0 table #5: started
2022/07/06-15:01:32.029223 139755618563840 Level-0 table #5: 1887662 bytes OK
2022/07/06-15:01:32.032375 139755618563840 Delete type=0 #3
```

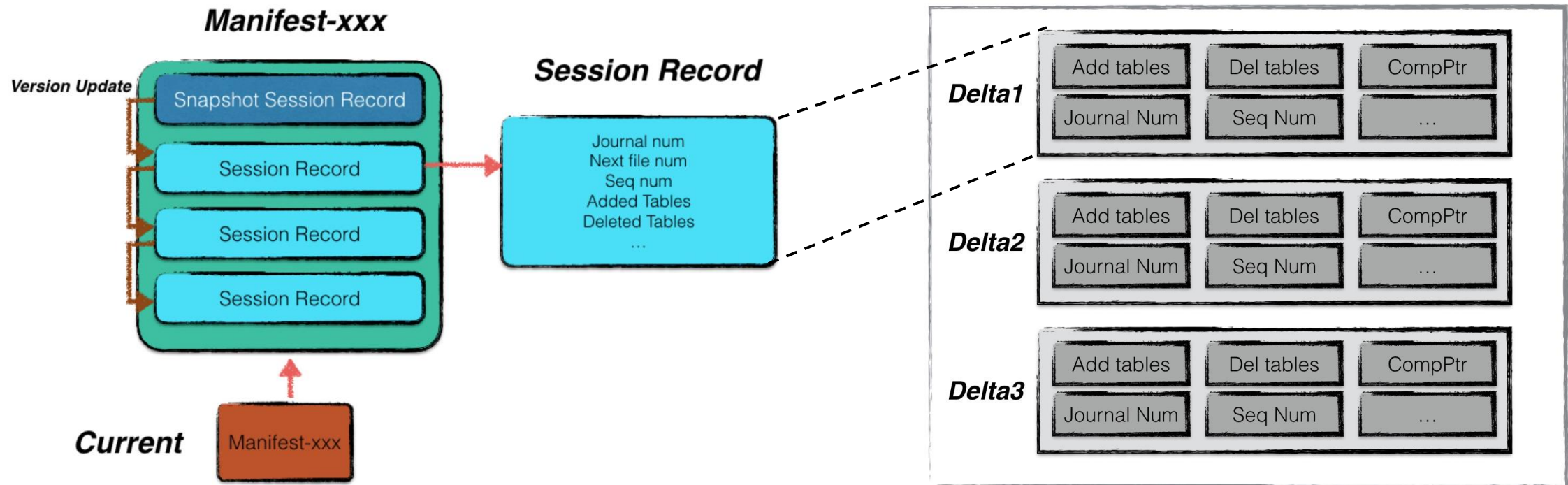
Log

- Log Data (Contents)
 - Header
 - Sequence number
 - Num of entries
 - Data
 - Batch data



<https://leveldb-handbook.readthedocs.io/zh/latest/>

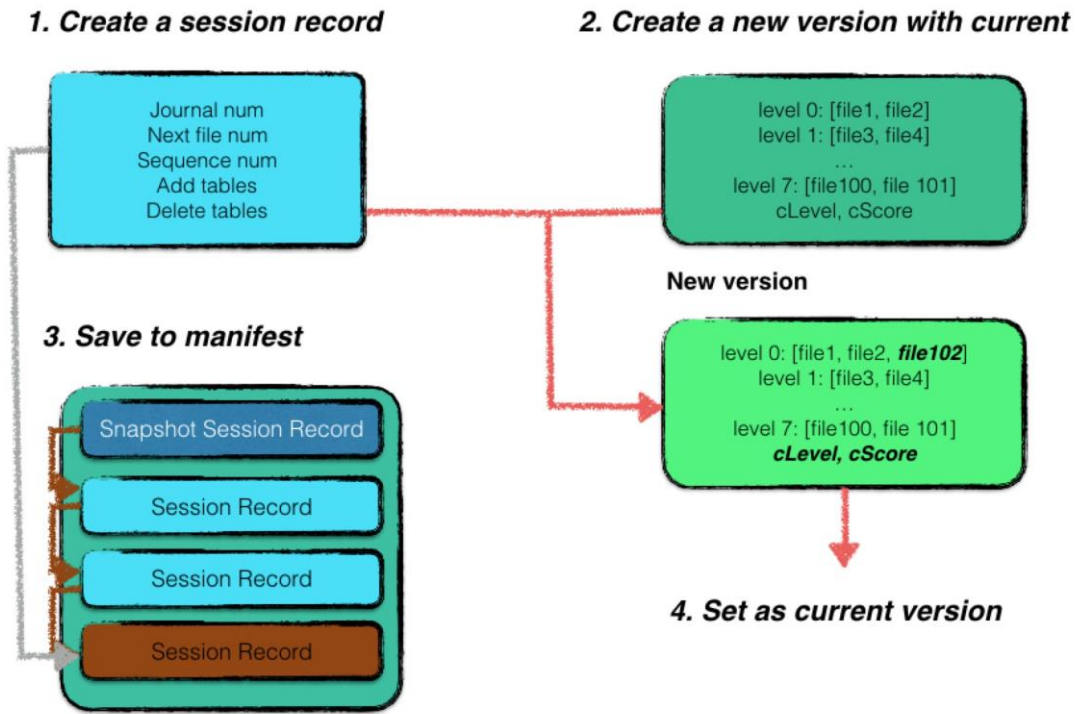
Manifest



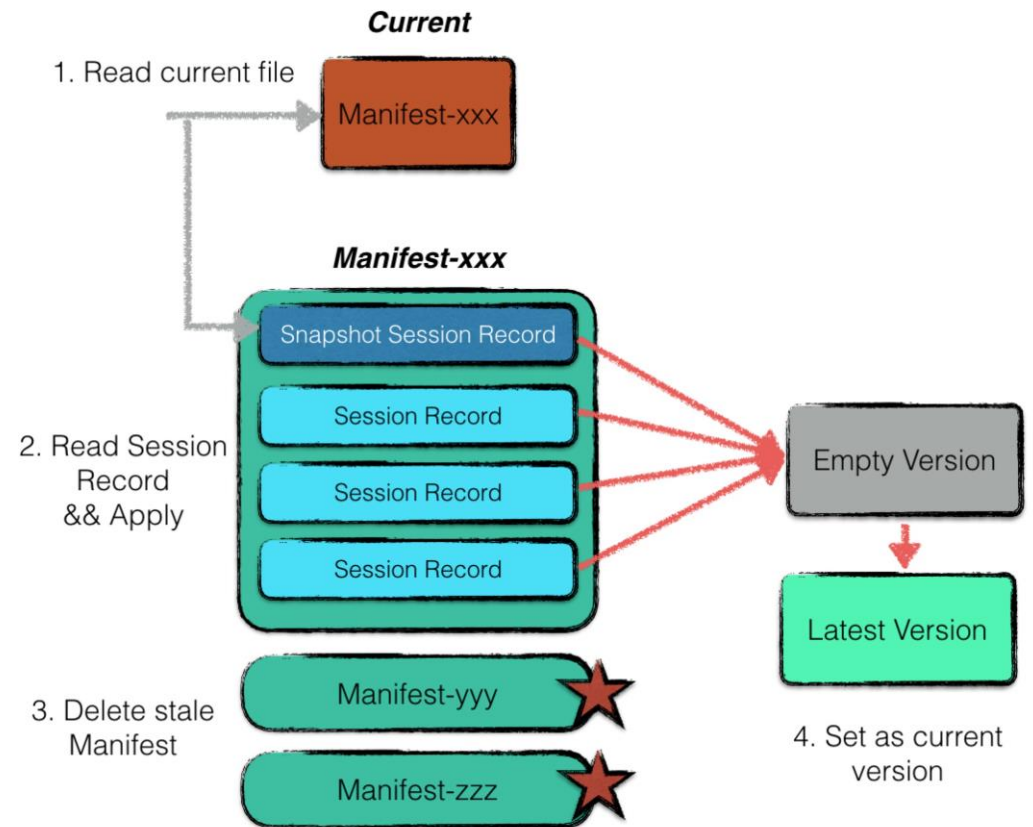
<https://leveldb-handbook.readthedocs.io/zh/latest/>

Manifest

Commit



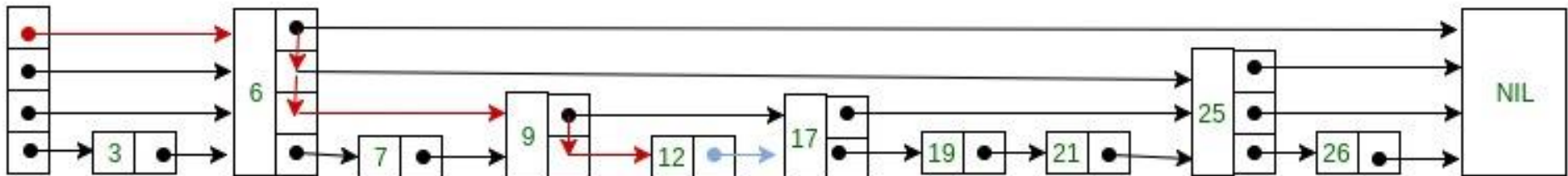
Recovery (DB open)



<https://leveldb-handbook.readthedocs.io/zh/latest/>

Memtable

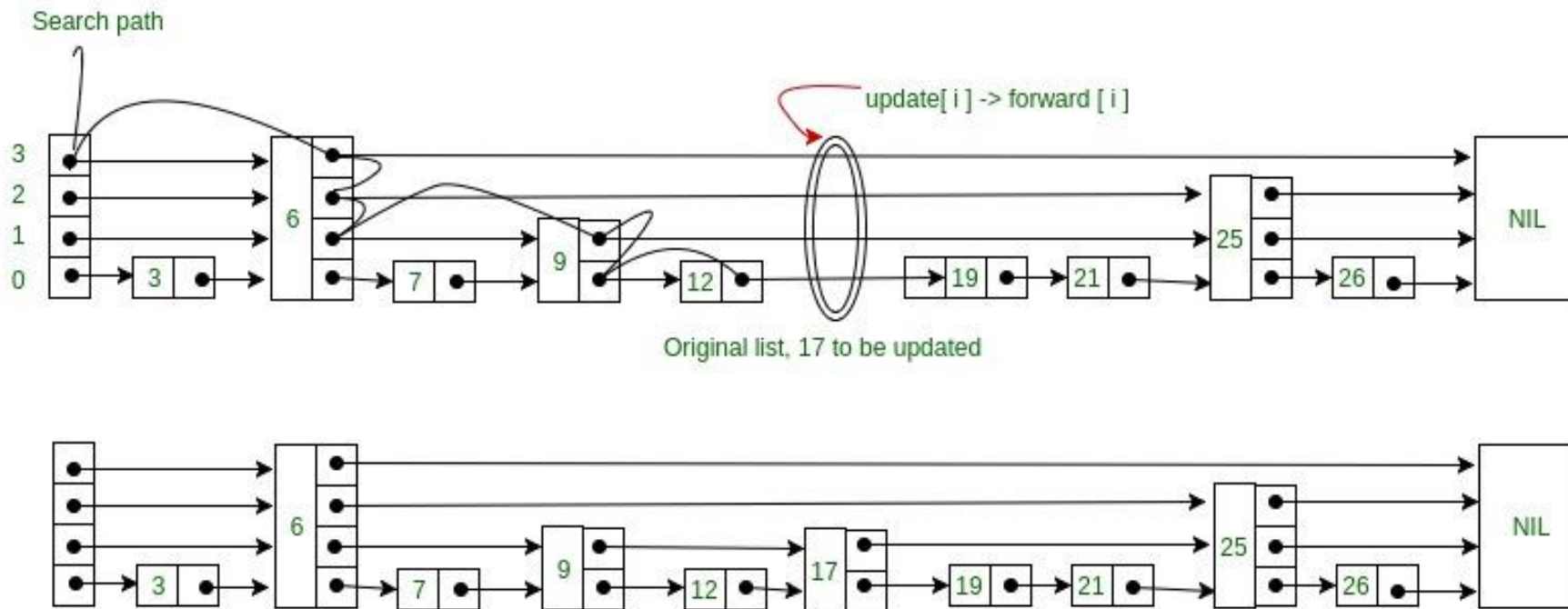
- KV pairs in memory, managed by Skiplist
- Skiplist: a data structure with a set of sorted linked lists
 - All keys appears in the last list
 - Some keys also appear in the upper list (for fast search)
- Good for both lookup and scan
 - Get the benefits of both Binary Tree and List
 - Useful in multi - threaded system architectures



<https://www.geeksforgeeks.org/skip-list-set-3-searching-deletion/?ref=lbp>

Memtable

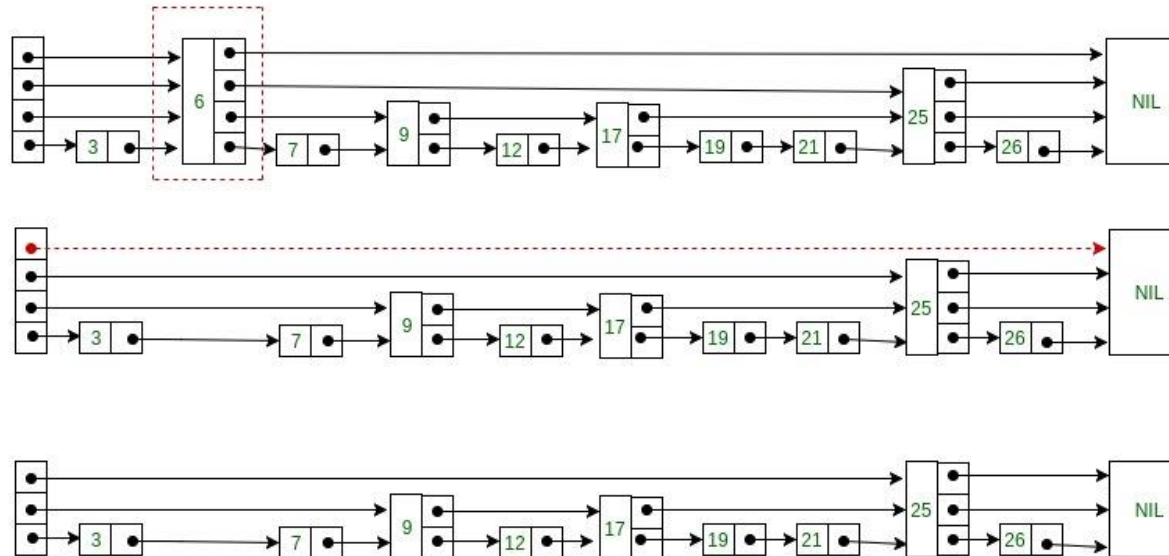
- Skiplist
 - (Search 17) -> Insert 17



<https://www.geeksforgeeks.org/skip-list-set-2-insertion/?ref=lbp>

Memtable

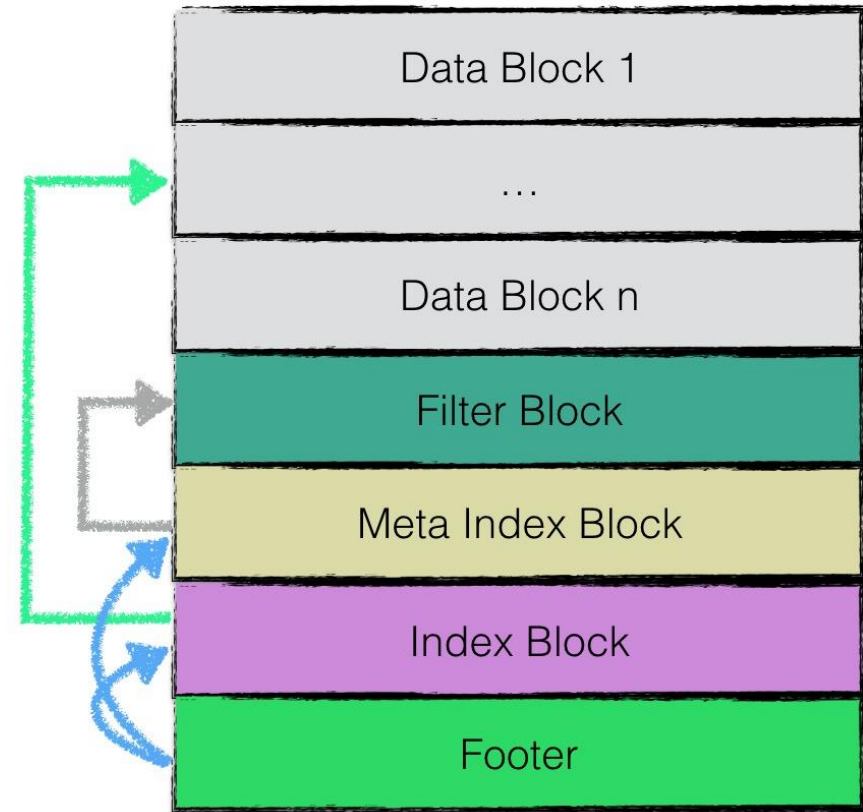
- Skiplist
 - Delete 6
 - No deletion in LevelDB
 - Just out-place update with sequence number



<https://www.geeksforgeeks.org/skip-list-set-3-searching-deletion/?ref=lbp>

SSTable

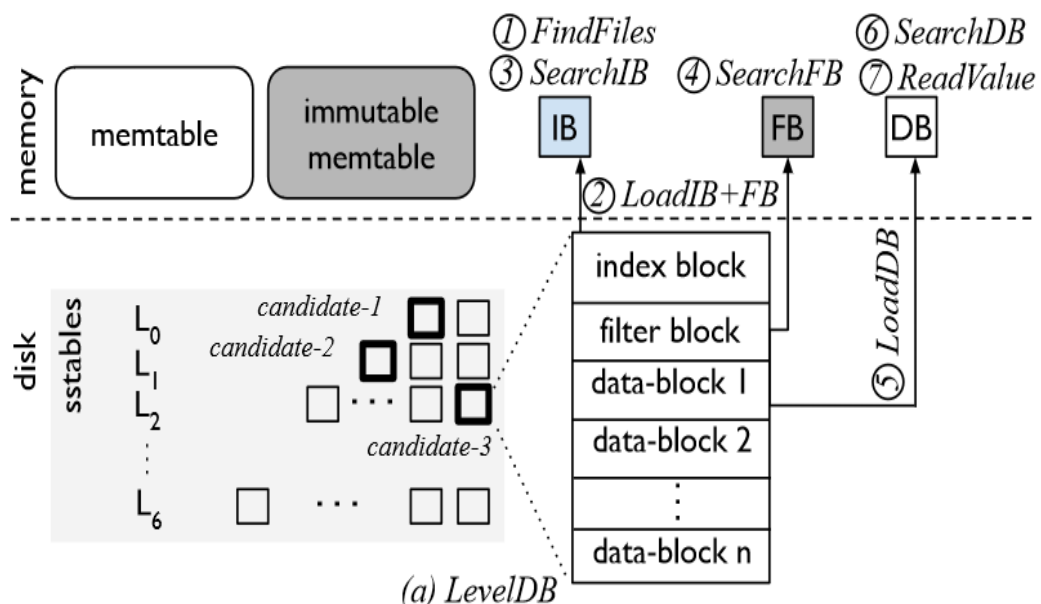
- Structure
 - Data block
 - Filter block
 - Bloom filter
 - Meta index block
 - Index of filter block
 - Index block
 - Index of data block
 - Footer
 - Index of meta-index / index



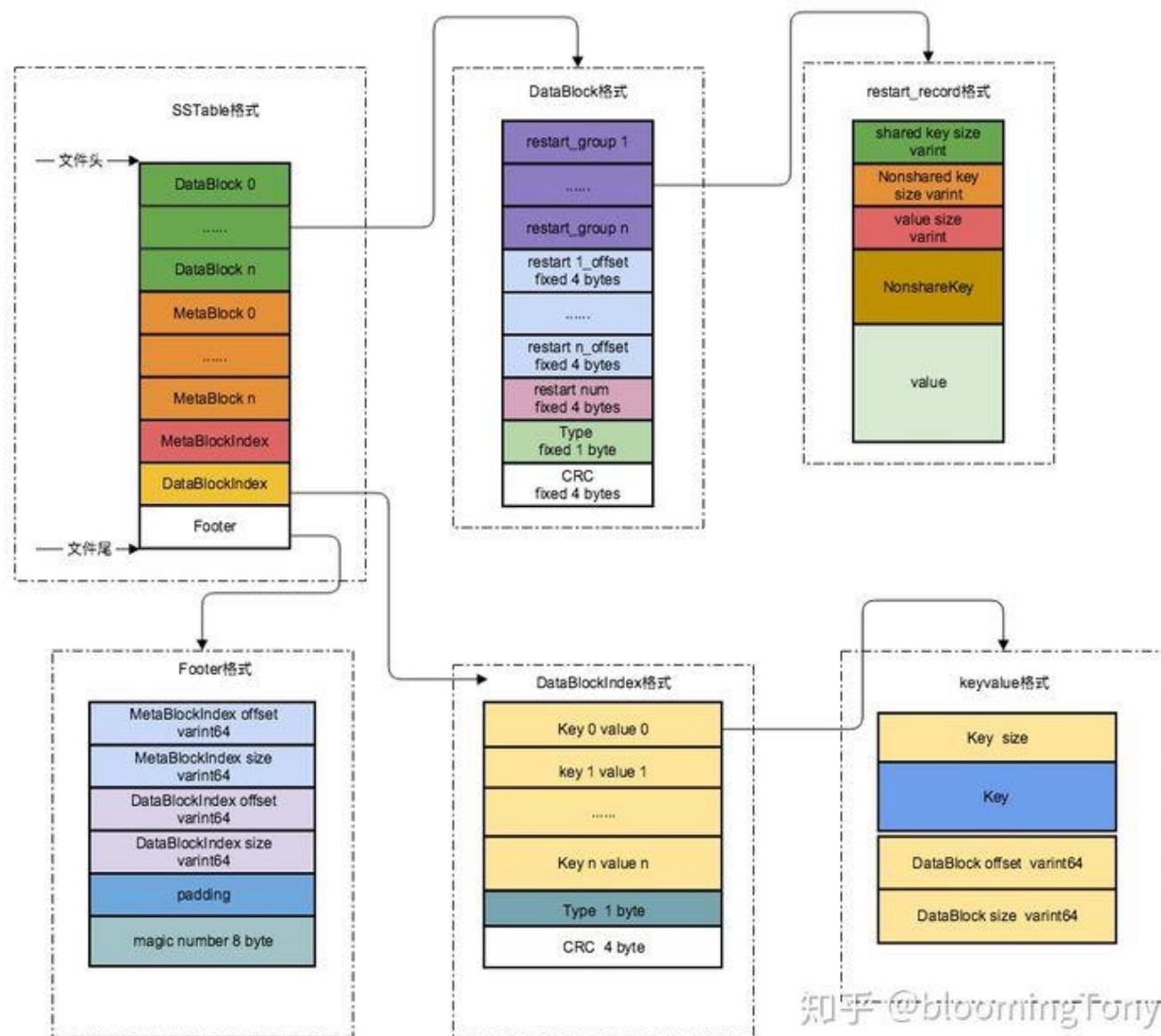
<https://leveldb-handbook.readthedocs.io/zh/latest/>

SSTable

Read KV from SST



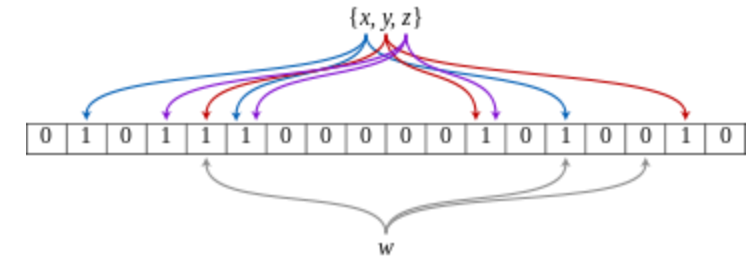
Yifan Dai, From WiscKey to Bourbon, OSDI '20



<https://zhuanlan.zhihu.com/p/37633790>

Bloom Filter

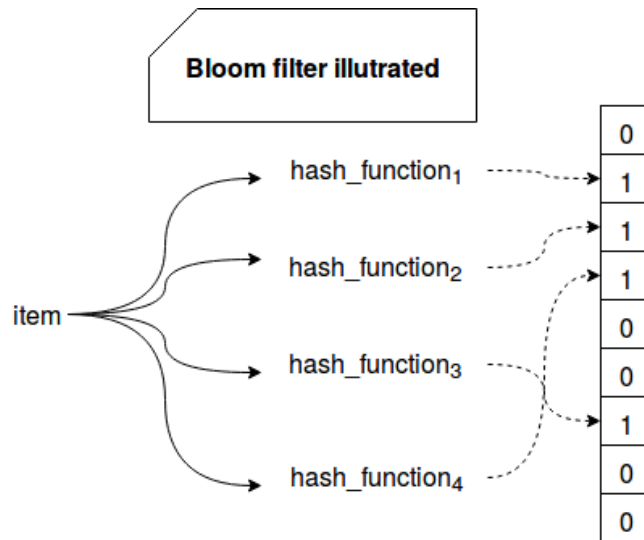
- Used to reduce the read amplification (unnecessary read)
- Bloom filter: a data structure for identifying membership
 - Based on bits and multiple hashes
 - Good property: No false negative
 - Issue: can yield false positives
 - tradeoffs between bits and rate
 - 1% false positive rate with 9.9 bits per key, from RocksDB wiki
- Not only SSTable (per SSTable or per block) but also Memtable



https://en.m.wikipedia.org/wiki/File:Bloom_filter.svg

```
void CreateFilter(const Slice* keys, int n, std::string* dst) const override {  
    // Compute bloom filter size (in both bits and bytes)  
    size_t bits = n * bits_per_key_;  
  
    // For small n, we can see a very high false positive rate. Fix it  
    // by enforcing a minimum bloom filter length.  
    if (bits < 64) bits = 64;  
  
    size_t bytes = (bits + 7) / 8;  
    bits = bytes * 8;
```

Bloom Filter



<https://www.waitingforcode.com/big-data-algorithms/bloom-filter/read>

| | | Actual | |
|-----------|----------|----------------|----------------|
| | | Positive | Negative |
| Predicted | Positive | True Positive | False Positive |
| | Negative | False Negative | True Negative |

<https://commons.wikimedia.org/wiki/File:ConfusionMatrixRedBlue.png>

1. Add items to bloom filter using a hash function



2. Bloom filter containing "Monday," "Thursday," "Friday"



3. To look up "Saturday," generate a hash for "Saturday" ...



4. ...and compare to the bloom filter



Yes

Yes

No

"Saturday" is not in the set of items in the bloom filter.

<https://numenta.com/blog/2012/10/07/wait-the-brain-is-a-bloom-filter/>

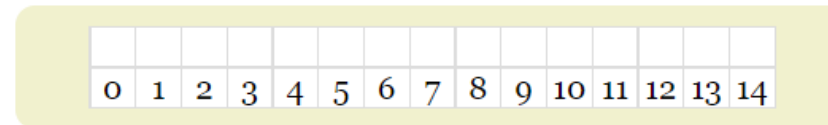
Bloom Filter

Bloom Filters by Example

A Bloom filter is a data structure designed to tell you, rapidly and memory-efficiently, whether an element is present in a set.

The price paid for this efficiency is that a Bloom filter is a **probabilistic data structure**: it tells us that the element either *definitely is not* in the set or *may be* in the set.

The base data structure of a Bloom filter is a **Bit Vector**. Here's a small one we'll use to demonstrate:



| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|
| | | | | | | | | | | | | | | |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |

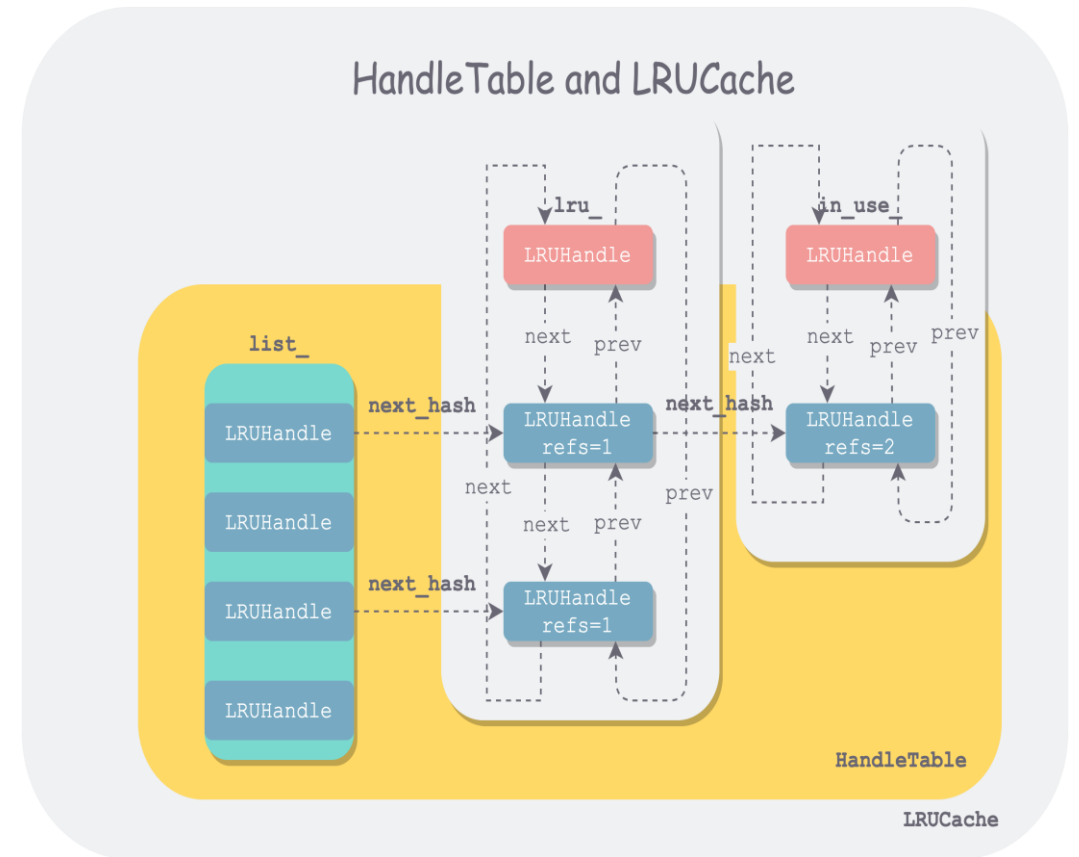
Each empty cell in that table represents a bit, and the number below it its index. To add an element to the Bloom filter, we simply hash it a few times and set the bits in the

Online bloom filter practice, excellent visualization

<https://lilimlib.github.io/bloomfilter-tutorial/>

Cache

- Cache uncompressed block
- Multi-threading support
- Data structure
 - Hash + array + 2 double linked list
 - 2 Double linked list
 - In_use_, lru_

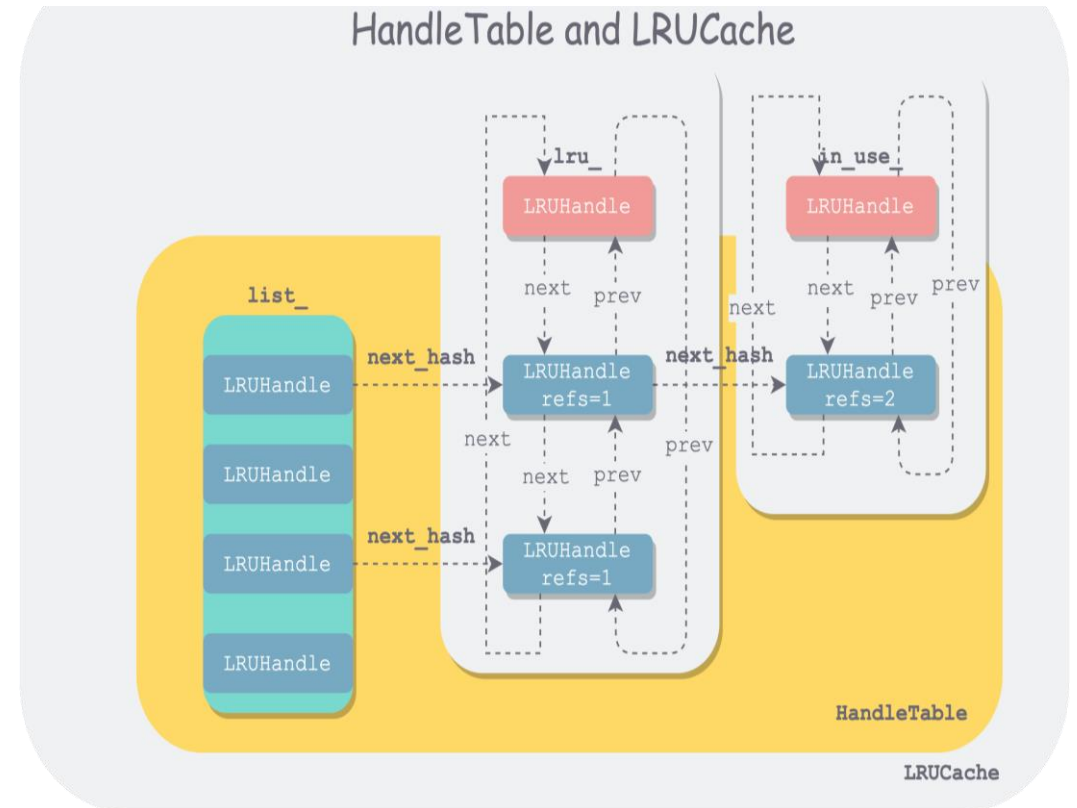
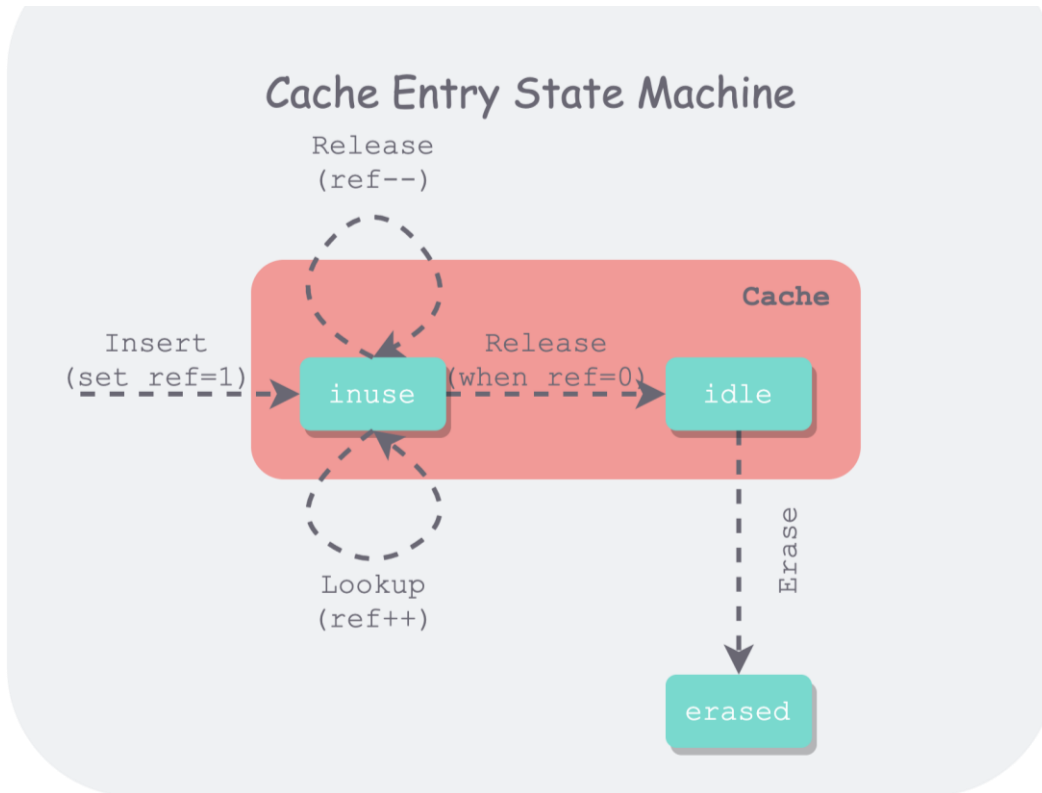


[木鸟杂记, Talking about LevelDB data structure \(CHS\), 2021](#)

Cache

■ Ref

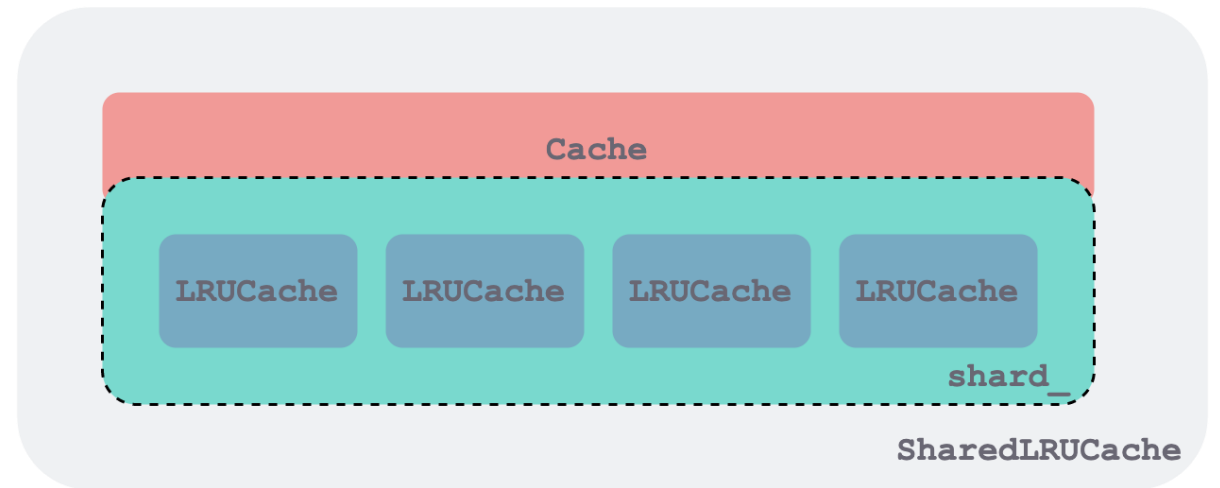
- $\text{ref} = 2 \text{ (in_use_ \&\& lru_)} / \text{ref} = 1 \text{ (!in_use_ \&\& lru_)} / \text{ref} = 0 \text{ (!in_use_ \&\& !lru_)}$



[木鸟杂记, Talking about LevelDB data structure \(CHS\), 2021](#)

Cache

- Lock
 - Mutex_
- Sharding
 - For locking granularity
 - coarse/fine grained
 - 16 shards



[木鸟杂记, Talking about LevelDB data structure \(CHS\), 2021](#)

- 1. LevelDB Architecture
- 2. Key-Value Interface
- 3. Internal Operations
- 4. Data Structure
- 5. LevelDB Installation
- 6. db_bench experiment
- 7. References
- 8. Homework

■ LevelDB Installation

✓ LevelDB install

- Release Mode
- Debug Mode

✓ db_bench

- Benchmark, Option, Command
- Shell script

LevelDB Install

- Install LevelDB twice separately
 - Release mode
 - Experiment, Benchmark
 - Debug mode
 - Analysis

Release Mode

- Installation (posix)
 - Install guide is available at LevelDB repository
 - <https://github.com/google/leveldb>

```
$ sudo apt-get update
```

```
$ sudo apt-get install build-essential
```

```
$ sudo apt-get install cmake
```

```
$ git clone --recurse-submodules https://github.com/google/leveldb.git \
  leveldb_release
```

```
$ cd leveldb_release
```

```
$ mkdir -p build && cd build
```

```
$ cmake -DCMAKE_BUILD_TYPE=Release .. && cmake --build .
```

- Test
 - \$./db_bench (dir: leveldb_release/build)

Getting the Source

```
git clone --recurse-submodules https://github.com/google/leveldb.git
```

Building

This project supports CMake out of the box.

Build for POSIX

Quick start:

```
mkdir -p build && cd build
cmake -DCMAKE_BUILD_TYPE=Release .. && cmake --build .
```

<https://github.com/google/leveldb/blob/main/README.md>

Debug Mode

- Installation (posix)

```
$ git clone --recurse-submodules \
  https://github.com/google/leveldb.git leveldb_debug
$ cd leveldb_debug
```

- Add '-g', '-pg' gcc option on leveldb/CMakeLists.txt

- -g : debug option
- -pg : gprof option
- \$ vi CMakeLists.txt
- + set(CMAKE_CXX_FLAGS "\${CMAKE_CXX_FLAGS} -g -pg")

- Build

```
$ mkdir -p build && cd build
$ cmake -DCMAKE_BUILD_TYPE=Debug .. && cmake --build .
```

- Test

```
$ ./db_bench (dir: leveldb_debug/build)
```

2. Add -g -pg option on leveldb/CMakeList.txt

```
+ # Add -g -pg option for gdb, ufttrace
+ set(CMAKE_CXX_FLAGS "${CMAKE_CXX_FLAGS} -g -pg")

if(CMAKE_CXX_COMPILER_ID STREQUAL "MSVC")
  # Disable C++ exceptions.
```

-g Produce debugging information in the operating system's native format (stabs, COFF, XCOFF, or DWARF). GDB can work with this debugging information.

-pg Generate extra code to write profile information suitable for the analysis program **prof** (for **-p**) or **gprof** (for **-pg**). You must use this option when compiling the source files you want data about, and you must also use it when linking.

gcc(1) — Linux manual pag
(<https://man7.org/linux/man-pages/man1/gcc.1.html>)

db_bench

- LevelDB internal benchmark tool
 - Metrics
 - Throughput, latency, size ...
 - Trace code
 - gdb, uftace

```
mingu@sever:~/leveldb_release/build$ ./db_bench
LevelDB:    version 1.23
Date:       Fri Jul  8 21:38:00 2022
CPU:        16 * Intel(R) Core(TM) i7-10700K CPU @ 3.80GHz
CPUCache:   16384 KB
Keys:       16 bytes each
Values:     100 bytes each (50 bytes after compression)
Entries:    1000000
RawSize:    110.6 MB (estimated)
FileSize:   62.9 MB (estimated)

-----
fillseq      :      1.159 micros/op;   95.5 MB/s
fillsync     :    2441.636 micros/op;    0.0 MB/s (1000 ops)
fillrandom   :      2.259 micros/op;   49.0 MB/s
overwrite    :      2.833 micros/op;   39.1 MB/s
readrandom   :      2.795 micros/op; (864322 of 1000000 found)
readrandom   :      2.336 micros/op; (864083 of 1000000 found)
readseq      :      0.108 micros/op; 1020.7 MB/s
readreverse  :      0.166 micros/op;  666.8 MB/s
compact      :   528715.000 micros/op;
readrandom   :      1.821 micros/op; (864105 of 1000000 found)
readseq      :      0.093 micros/op; 1183.2 MB/s
readreverse  :      0.149 micros/op;  740.8 MB/s
fill100K     :      747.593 micros/op;  127.6 MB/s (1000 ops)
crc32c       :      0.868 micros/op; 4502.8 MB/s (4K per op)
snappycomp   :      2.273 micros/op; 1718.3 MB/s (output: 55.1%)
snappyuncomp :      0.385 micros/op; 10147.6 MB/s
```

Environment setup

(0) root mode

\$ sudo su

(1) disable swap entirely to avoid performance problems and inconsistencies

\$ swapoff --all

(2) disable zone_reclaim_mode

\$ echo 0 > /proc/sys/vm/zone_reclaim_mode

(3) maximum open file

\$ sysctl fs.file-max

\$ sysctl -w fs.file-max=5000000

(4) Log out

\$ exit

```
mingu@sever:~/leveldb_release/build$ sudo su
root@sever:/home/mingu/leveldb_release/build# swapoff --all
root@sever:/home/mingu/leveldb_release/build# echo 0 > /proc/sys/vm/zone_reclaim_mode
root@sever:/home/mingu/leveldb_release/build# sysctl fs.file-max
fs.file-max = 9223372036854775807
root@sever:/home/mingu/leveldb_release/build# sysctl -w fs.file-max=5000000
fs.file-max = 5000000
root@sever:/home/mingu/leveldb_release/build# sysctl -w fs.file-max=9223372036854775807
fs.file-max = 9223372036854775807
```

Options

- All db_bench options are written in
 - `leveldb/benchmarks/db_bench.cc`
- Actual Benchmarks
 - `fillseq`
 - `fillrandom`
 - `readrandom`
 - `readseq`
- Meta operations
 - `compact`
 - `stats`
 - `sstables`

`leveldb / benchmarks / db_bench.cc`

```
// Comma-separated list of operations to run in the specified order
// Actual benchmarks:
// fillseq      -- write N values in sequential key order in async mode
// fillrandom   -- write N values in random key order in async mode
// overwrite    -- overwrite N values in random key order in async mode
// fillsync     -- write N/100 values in random key order in sync mode
// fill100K     -- write N/1000 100K values in random order in async mode
// deleteseq    -- delete N keys in sequential order
// deleterandom -- delete N keys in random order
// readseq      -- read N times sequentially
// readreverse  -- read N times in reverse order
// readrandom   -- read N times in random order
// readmissing  -- read N missing keys in random order
// readhot      -- read N times in random order from 1% section of DB
// seekrandom   -- N random seeks
// seekordered  -- N ordered seeks
// open         -- cost of opening a DB
// crc32c       -- repeated crc32c of 4K of data
// Meta operations:
// compact      -- Compact the entire DB
// stats        -- Print DB stats
// sstables     -- Print sstable info
// heapprofile   -- Dump a heap profile (if supported by this port)
```


Options

- All db_bench options are written in
 - leveldb/benchmarks/db_bench.cc

- Options

--histogram: latency histogram

--db: directory of db

--use_existing_db: true/false

--num: num of key-value pairs

--read: num of reads

--value_size(byte): size of value

--threads: num of threads

--cache_size(byte): size of block cache

--bloom_bits(bits): Bloom filter bits per key.

--max_file_size: max size of SSTable

```
65 // Number of key/values to place in database
66 static int FLAGS_num = 1000000;
67
68 // Number of read operations to do. If negative, do FLAGS_num reads.
69 static int FLAGS_reads = -1;
70
71 // Number of concurrent threads to run.
72 static int FLAGS_threads = 1;
73
74 // Size of each value
75 static int FLAGS_value_size = 100;
76
77 // Arrange to generate values that shrink to this fraction of
78 // their original size after compression
79 static double FLAGS_compression_ratio = 0.5;
80
81 // Print histogram of operation timings
82 static bool FLAGS_histogram = false;
83
84 // Count the number of string comparisons performed
85 static bool FLAGS_comparisons = false;
86
87 // Number of bytes to buffer in memtable before compacting
88 // (initialized to default value by "main")
89 static int FLAGS_write_buffer_size = 0;
90
91 // Number of bytes written to each file.
92 // (initialized to default value by "main")
93 static int FLAGS_max_file_size = 0;
94
95 // Approximate size of user data packed per block (before compression).
96 // (initialized to default value by "main")
97 static int FLAGS_block_size = 0;
98
99 // Number of bytes to use as a cache of uncompressed data.
100 // Negative means use default settings.
101 static int FLAGS_cache_size = -1;
102
103 // Maximum number of files to keep open at the same time (use default if == 0)
104 static int FLAGS_open_files = 0;
105
106 // Bloom filter bits per key.
107 // Negative means use default settings.
108 static int FLAGS_bloom_bits = -1;
109
110 // Common key prefix length.
111 static int FLAGS_key_prefix = 0;
112
113 // If true, do not destroy the existing database. If you set this
114 // flag and also specify a benchmark that wants a fresh database, that
115 // benchmark will fail.
116 static bool FLAGS_use_existing_db = false;
117
118 // If true, reuse existing log/MANIFEST files when re-opening a database.
119 static bool FLAGS_reuse_logs = false;
120
121 // Use the db with the following name.
122 static const char* FLAGS_db = nullptr;
```

```
1021 int main(int argc, char** argv) {
1022     FLAGS_write_buffer_size = leveldb::Options().write_buffer_size;
1023     FLAGS_max_file_size = leveldb::Options().max_file_size;
1024     FLAGS_block_size = leveldb::Options().block_size;
1025     FLAGS_open_files = leveldb::Options().max_open_files;
1026     std::string default_db_path;
1027
1028     for (int i = 1; i < argc; i++) {
1029         double d;
1030         int n;
1031         char junk;
1032         if (leveldb::Slice(argv[i]).starts_with("--benchmarks=")) {
1033             FLAGS_benchmarks = argv[i] + strlen("--benchmarks=");
1034         } else if (sscanf(argv[i], "--compression_ratio=%lf%c", &d, &junk) == 1) {
1035             FLAGS_compression_ratio = d;
1036         } else if (sscanf(argv[i], "--histogram=%d%c", &n, &junk) == 1 &&
1037             (n == 0 || n == 1)) {
1038             FLAGS_histogram = n;
1039         } else if (sscanf(argv[i], "--comparisons=%d%c", &n, &junk) == 1 &&
1040             (n == 0 || n == 1)) {
1041             FLAGS_comparisons = n;
1042         } else if (sscanf(argv[i], "--use_existing_db=%d%c", &n, &junk) == 1 &&
1043             (n == 0 || n == 1)) {
1044             FLAGS_use_existing_db = n;
1045         } else if (sscanf(argv[i], "--reuse_logs=%d%c", &n, &junk) == 1 &&
1046             (n == 0 || n == 1)) {
1047             FLAGS_reuse_logs = n;
1048         } else if (sscanf(argv[i], "--num=%d%c", &n, &junk) == 1) {
1049             FLAGS_num = n;
1050         } else if (sscanf(argv[i], "--reads=%d%c", &n, &junk) == 1) {
1051             FLAGS_reads = n;
1052         } else if (sscanf(argv[i], "--threads=%d%c", &n, &junk) == 1) {
1053             FLAGS_threads = n;
1054         } else if (sscanf(argv[i], "--value_size=%d%c", &n, &junk) == 1) {
1055             FLAGS_value_size = n;
1056         } else if (sscanf(argv[i], "--write_buffer_size=%d%c", &n, &junk) == 1) {
1057             FLAGS_write_buffer_size = n;
1058         } else if (sscanf(argv[i], "--max_file_size=%d%c", &n, &junk) == 1) {
1059             FLAGS_max_file_size = n;
1060         } else if (sscanf(argv[i], "--block_size=%d%c", &n, &junk) == 1) {
1061             FLAGS_block_size = n;
1062         } else if (sscanf(argv[i], "--key_prefix=%d%c", &n, &junk) == 1) {
1063             FLAGS_key_prefix = n;
1064         } else if (sscanf(argv[i], "--cache_size=%d%c", &n, &junk) == 1) {
1065             FLAGS_cache_size = n;
1066         } else if (sscanf(argv[i], "--bloom_bits=%d%c", &n, &junk) == 1) {
1067             FLAGS_bloom_bits = n;
1068         } else if (sscanf(argv[i], "--open_files=%d%c", &n, &junk) == 1) {
1069             FLAGS_open_files = n;
1070         } else if (strncmp(argv[i], "--db=", 5) == 0) {
1071             FLAGS_db = argv[i] + 5;
```

Metrics

- Default
 - Throughput (micros/op, MB/s)
- --histogram
 - Latency
- --benchmarks="stats"
 - Stats of SSTs
 - Num of file, Size of db / read /write
- --benchmarks="**any_bench**,stats,compact,stats"
 - SAF

```
mingu@sever:~/leveldb_release/build$ sudo su
[sudo] password for mingu:
root@sever:/home/mingu/leveldb_release/build# sh bench_script
./db_bench --use_existing_db=0 --compression_ratio=1 --comparis

LevelDB:    version 1.23
Date:       Sat Jul  9 16:36:24 2022
CPU:        16 * Intel(R) Core(TM) i7-10700K CPU @ 3.80GHz
CPUCache:   16384 KB
Keys:       16 bytes each
Values:     100 bytes each (100 bytes after compression)
Entries:    500000
RawSize:    55.3 MB (estimated)
FileSize:   55.3 MB (estimated)

-----
fillrandom  :      2.006 micros/op;   55.2 MB/s
Microseconds per op:
Count: 500000 Average: 2.0056 StdDev: 24.67
Min: 0.0000 Median: 1.8774 Max: 5425.0000

-----
[      0,      1 )      13   0.003%   0.003%
[      1,      2 ) 284903 56.981% 56.983% #####
[      2,      3 ) 193588 38.718% 95.701% #####
[      3,      4 )  17748  3.550% 99.250% #
[      4,      5 )   2395  0.479% 99.729%
[      5,      6 )    280  0.056% 99.785%
[      6,      7 )    110  0.022% 99.807%
```

```
Comparisons: 23384945

                                Compactions
Level  Files  Size(MB)  Time(sec)  Read(MB)  Write(MB)
-----
  0      0      0         0         0         47
  1      0      0         0         60         53
  2     19     34         1         95         88
```

Shell script

- Run db_bench with shell script
 - \$ sh bench_script.sh
 - https://github.com/DKU-StarLab/leveldb-study/blob/main/Introduction/bench_script.sh
- Contents
 - Environment setup
 - Option
 - Sample command
 - Record result
 - echo | tee -a result.txt
- If/For statement

```
# -----3. Run db_bench-----
# clearing kernel buffers before running each workload.
sync; echo 3 > /proc/sys/vm/drop_caches

# sample db_bench command
CMD="./db_bench \
--use_existing_db=0 \
--histogram=1 \
--compression_ratio=1 \
--comparisons=1 \
--benchmarks="fillrandom,stats,readrandom,stats" \
--num=500000 \
--reads=300000 \
--bloom_bits=0 \
"

echo "$CMD" | tee -a result.txt
echo | tee -a result.txt

RESULT=$( $CMD )

echo "$RESULT" | tee -a result.txt
echo | tee -a result.txt
# -----
```

1. LevelDB Architecture
2. Key-Value Interface
3. Internal Operations
4. Data Structure
5. LevelDB Installation
6. db_bench experiment
7. References
8. Homework

- db_bench experiment
 - ✓ Choose your topic
 - ✓ options / benchmarks / metrics
 - ✓ 5 steps of experiments

Choose your topic

- 6 Topics, 6 Teams
 - Memtable
 - WAL/Manifest
 - Compaction
 - SSTable
 - Bloom Filter
 - Cache
- Submit topics what you interested in
 - Deadline: 7/13, 11:00AM
 - <https://github.com/DKU-StarLab/leveldb-study/issues/3>

Options, Benchmarks, Metrics

| LevelDB | | | |
|-------------|------------------------------------|--|-----------------------------------|
| | Options | Benchmarks | Metrics |
| Memtable | write_buffer_size max_file_size | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |
| SSTable | max_file_size block_size | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |
| BloomFilter | bloom_bits (On/Off) | Readmissing Readrandom Seekrandom | Throughput Latency WAF, SAF |
| Cache | cache_size block_size | Readhot Readseq Readrandom Seekrandom | Throughput Latency RAF |

Options, Benchmarks, Metrics

| RocksDB | | | |
|------------|---|-------------------------------------|-----------------------------------|
| | Options | Benchmarks | Metrics |
| Compaction | -base_background_compactions -compaction_style (level-based, universal, fifo) | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |
| WAL | - disable_wal - wal_bytes_per_sync | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |

5 steps of experiment

1. hypotheses

- If option changes, what changes will happen internally?
- How will internal changes affect the metrics?
 - What result/graph do you expect?
- Why???

5 steps of experiment

2. Design

- Do the simplest and smallest experiment that can test your hypothesis.
- Do not experiment with multiple variables at once from the beginning
- Don't let uncontrolled variables ruin your experiment.

5 steps of experiment

2. Design

- Independent variable
 - Num of kv pairs
 - Options and benchmarks
- Dependent variable
 - Throughput, Latency, WAF/RAF ...
 - DB size(SAF)
- Controlled variable
 - Initial OS cache, other processes
 - Compile option (-g, -pg)
 - Default options (compression, bloom filter, cache, num, reads, using existing db)

5 steps of experiment

3. Run Experiment

- Use shell script or python script
 - Use echo for check your script is running correctly
- Use redirection to record result from shell
- Do not use leveldb which complied with debug/profile options
- Turn off other processes

5 steps of experiment

4. Result and Discussion

- Verify your idea/hypothesis with result data.
- Explain why your hypothesis is correct or not.

5 steps of experiment

5. Present your experiment in 10 minutes

- 1. Hypotheses
- 2. Design
- 3. Environment
- 4. Result and Discussion
 - Extra 5 min for Discussion

■ Previous study presentation example

- https://github.com/DKU-StarLab/RocksDB_Festival

Notice

- Upload your presentation file through pull request
 - Make pull request until 7/19 11AM
 - `leveldb-study/analysis/benchmark/`
- PPT format is uploaded in github introduction folder
 - Format: `[your topic] benchmark analysis.pdf`
 - <https://github.com/DKU-StarLab/leveldb-study/tree/main/Introduction>
- The week after next
 - write a document that explains your experiment
 - upload in git-book

1. LevelDB Architecture
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- References
 - ✓ Documents
 - ✓ Lectures

Documents

leveldb

Jeff Dean, Sanjay Ghemawat

The leveldb library provides a persistent key value store. Keys and values are arbitrary byte arrays. The keys are ordered within the key value store according to a user-specified comparator function.

Opening A Database

A leveldb database has a name which corresponds to a file system directory. All of the contents of database are stored in this directory. The following example shows how to open a database, creating it if necessary:

```
#include <cassert>
#include "leveldb/db.h"

leveldb::DB* db;
leveldb::Options options;
options.create_if_missing = true;
leveldb::Status status = leveldb::DB::Open(options, "/tmp/testdb", &db);
assert(status.ok());
...
```

If you want to raise an error if the database already exists, add the following line before the `leveldb::DB::Open` call:

leveldb/doc/

facebook / rocksdbPublic

Watch1kFork5.3kStar22.9k

<> CodeIssues425Pull requests270ActionsProjectsWikiSecurityInsights

Home

cheng-chang edited this page on 19 Jan · 57 revisions

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Welcome to RocksDB

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RocksDB Public Communication and Information Channels

Basic Operations

Iterator

Prefix seek

SeekForPrev

Tailing Iterator

Compaction Filter

Read-Modify-Write (Merge) Operator

Column Families

Creation and Ingestion SST files

Features

- Designed for application servers wanting to store up to a few terabytes of data on local or remote storage systems.
- Optimized for storing small to medium size key-values on fast storage -- flash devices or in-memory
- It works well on processors with many cores

Features Not in LevelDB

rocksdb github wiki

Documents

leveldb-handbook

latest

Search docs

内容:

- 基本概念
- 读写操作
- 日志
- 内存数据库
- sstable
- 缓存系统
- 布隆过滤器
- compaction
- 版本控制



Digital Ocean: Create your world-changing apps on the cloud developers love Try now with a \$100 Credit

Ad by EthicalAds · Monetize your site

Docs » leveldb-handbook

leveldb-handbook

内容:

- 基本概念
 - 整体架构
- 读写操作
 - 写操作
 - 读操作
 - 读取
- 日志
 - 日志结构
 - 日志内容
 - 日志写
 - 日志读
- 内存数据库
 - 跳表
 - 内存数据库
- sstable
 - 概述
 - SStable文件格式
 - data block结构
 - filter block结构

<https://leveldb-handbook.readthedocs.io/zh/latest/>

rsy56640 / read_and_analyse_levelDB Public

<> Code Issues Pull requests Actions Projects Wiki Security Insights

master read_and_analyse_levelDB / reference / Go to file

rsy56640 Update reference 76e3f1

..

DB leveldb实现解析.pdf ..

LevelDB源码分析.docx ..

LevelDB源码分析.pdf ..

README.md Update reference

bigtable-osdi06.pdf ..

leveldb-handbook.pdf ..

lsmtree.pdf ..

README.md

Reference

- leveldb实现解析 - 淘宝-核心系统研发-存储
- leveldb-handbook
- LevelDB: Read the Fucking Source Code.
- leveldb - 超全讲解.....
- LevelDB源码分析 - 百度文库 100多页.....
- The principle of LevelDb analysis - 英文，很多文章的出处
- Leveldb代码阅读笔记 - codedump
- 存储引擎技术架构与内幕 (leveldb-1) #58

rsy56640/read_and_analyse_levelDB

Documents

LevelDB Introduction

Fenggang Wu
Oct. 17th, 2016

Fenggang Wu, 『LevelDB Introduction』, University of Minnesota CSci5980, 2016

DKU-StarLab / RocksDB_Festival Public

Dankook University RocksDB research/study

☆ 12 stars 🍴 8 forks

★ Starred

👁 Watch

Code

Issues

Pull requests

Actions

Projects

...

https://github.com/DKU-StarLab/RocksDB_Festival

Lectures

D-MOOC

이용안내

콘텐츠 검색

공지사항

Q&A

연관 사이트

로그인

상시 접수

비정형 빅데이터를 위한 키-밸류 DB

최종무 | 상시모집 | 학습 기간 2021.12.01 ~ 2030.12.31

| | | | |
|-------|-------|----------|-----------|
| 강좌 언어 | 강의 길이 | 권장 학습 시간 | 이수증 제공 여부 |
| 한국어 | 7 주 | 4 시간 | 미제공 |

신청현황 30 명 / 무제한

강좌소개

키-밸류 DB는 최근 주목받고 있는 비정형 빅데이터를 위한 데이터베이스임.
대표적인 예로 구글의 LevelDB, 페이스북의 RocksDB, 아마존의 Dynamo 등이 있음.

신청 기간
상시모집

제공 기관

[Jongmoo Choi, 『Key-Value DB for Unstructured data』, 2021](#)



LSM Trees

동영상 3개 · 조회수 68회 · 최종 업데이트: 2021. 7. 27.

GL Tech Tutorials



GL Tech Tutorials

구독

LSM trees (Log Structured Merge Trees) - Detailed video

GL Tech Tutorials

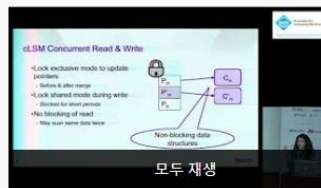
LSM trees (Log Structured Merge Trees) - Detailed write path | Part 1

GL Tech Tutorials

Bloom Filters in LSM Trees | Counting Bloom Filters | System Design

GL Tech Tutorials

[GL Tech Tutorials, 『LSM trees』, 2021](#)



leveldb

동영상 18개 · 조회수 2,542회 · 최종 업데이트: 2021. 11. 21.

Wei Zhou



Wei Zhou

구독

사용할 수 없는 동영상 1개가 숨겨졌습니다.

Scaling concurrent log-structured data stores

Association for Computing Machinery (ACM)

Intro to LevelDB

Kyle Robinson Young

Jeff Dean: "Achieving Rapid Response Times in Large Online Services" Keynote - Velocity 2014

O'Reilly

Learning LevelDB with Julian Gruber and Zeke Sikelianos

Zeke Sikelianos

[Wei Zhou, LevelDB YouTube playlist](#)

1. LevelDB Architecture
2. Key-Value Interface
3. Internal Operations
4. Data Structure
5. LevelDB Installation
6. db_bench experiment
7. References
8. Homework

■ Homework

✓ Submit your topic until 7/13 11AM

- Your team will be announced at 7/13 2PM

✓ Experiment and presentation

- Install Level DB
- Run Experiment
- Prepare presentation
- Pull request your presentation pdf file until 7/19 11AM

1. LevelDB Architecture
2. Key-Value Interface
3. Internal Operations
4. Data Structure
5. LevelDB Installation
6. db_bench experiment
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- Next week
 - ✓ Student presentation
 - Experiment
 - ✓ Lecture
 - How to analyze LevelDB

Thank you

Appendix

- How to install RocksDB

- Install guide

- <https://github.com/facebook/rocksdb/blob/main/INSTALL.md>

```
$ sudo apt-get update
```

```
$ sudo apt-get install build-essential
```

```
$ sudo apt-get install cmake
```

```
$ sudo apt-get install libgflags-dev
```

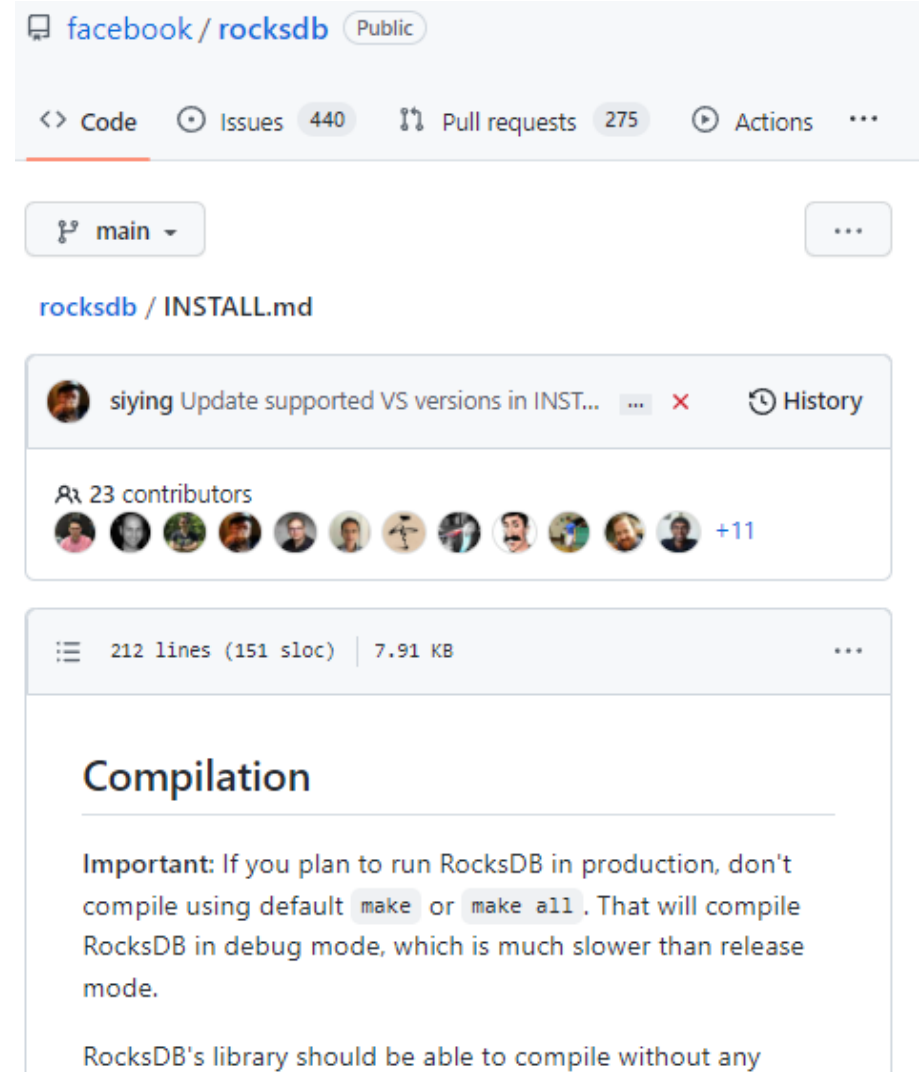
```
$ sudo apt-get install libsnappy-dev
```

```
$ git clone https://github.com/facebook/rocksdb.git
```

```
$ cd rocksdb
```

```
$ make db_bench -j (cpu_core)
```

```
$ db_bench
```



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main ...

rocksdb / INSTALL.md

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23 contributors

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Compilation

Important: If you plan to run RocksDB in production, don't compile using default `make` or `make all`. That will compile RocksDB in debug mode, which is much slower than release mode.

RocksDB's library should be able to compile without any

<https://github.com/facebook/rocksdb/blob/main/INSTALL.md>

Appendix

■ RocksDB db_bench option

Benchmarking tools

Ting Sun edited this page on 11 Feb · 6 revisions

db_bench

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`db_bench` is the main tool that is used to benchmark RocksDB's performance. RocksDB inherited `db_bench` from LevelDB, and enhanced it to support many additional options. `db_bench` supports many benchmarks to generate different types of workloads, and its various options can be used to control the tests.

If you are just getting started with `db_bench`, here are a few things you can try:

1. Start with a simple benchmark like `fillseq` (or `fillrandom`) to create a database and fill it with some data

```
./db_bench --benchmarks="fillseq"
```

If you want more stats, add the meta operator "stats" and `--statistics` flag.

```
./db_bench --benchmarks="fillseq,stats" --statistics
```

2. Read the data back

```
./db_bench --benchmarks="readrandom" --use_existing_db
```

You can also combine multiple benchmarks to the string that is passed to `--benchmarks` so that they run sequentially. Example:

```
./db_bench --benchmarks="fillseq,readrandom,readseq"
```

More in-depth example of `db_bench` usage can be found [here](#) and [here](#).

Contents

- RocksDB Wiki
- Overview
- RocksDB FAQ
- Terminology
- Requirements
- Contributors' Guide
- Release Methodology
- RocksDB Users and Use Cases
- RocksDB Public Communication and Information Channels
- Basic Operations
 - Iterator
 - Prefix seek
 - SeekForPrev
 - Tailing Iterator
 - Compaction Filter
 - Read-Modify-Write (Merge) Operator
 - Column Families
 - Creating and Ingesting SST files
 - Single Delete
 - Low Priority Write
 - Time to Live (TTL) Support
 - Transactions
 - Snapshot
 - DeleteRange
 - Atomic flush

<https://github.com/facebook/rocksdb/wiki/Benchmarking-tools>

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main rocksdb / tools / db_bench_tool.cc Go to file ...

mdcallag Set the value for --version, add --buil... ✓ Latest commit 177b2fa 4 days ago History

98 contributors +64

8567 lines (7708 sloc) 314 KB Raw Blame

```
1 // Copyright (c) 2011-present, Facebook, Inc. All rights reserved.
2 // This source code is licensed under both the GPLv2 (found in the
3 // COPYING file in the root directory) and Apache 2.0 License
4 // (found in the LICENSE.Apache file in the root directory).
5 //
```

https://github.com/facebook/rocksdb/blob/main/tools/db_bench_tool.cc

Appendix

| RocksDB | | | |
|------------|---|-------------------------------------|-----------------------------------|
| | Options | Benchmarks | Metrics |
| Compaction | -base_background_compactions -compaction_style (level-based, universal, fifo) | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |
| WAL | - disable_wal - wal_bytes_per_sync | Fillseq Fillrandom Readrandom | Throughput Latency WAF, SAF |