Simple Database

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Features

- Key type: C++ string
- Value type: array of bytes
- B+ tree index
- MMIO
- CURD supported
- Cross platform

Example

```
// create or open database
DatabaseOption option;
option.memory_limitation = 1024 * 1024 * 1024;
Database db("database_name", option);

// write
int value = 1;
db.set("1", (void *)&value, sizeof(value), false);
db.set<int>("2", 2, false);

// read
int value_length = db->get("1", (void *)&value);
db.get<int>("2"); // return 2

// remove
db.remove("1");
```

Architecture

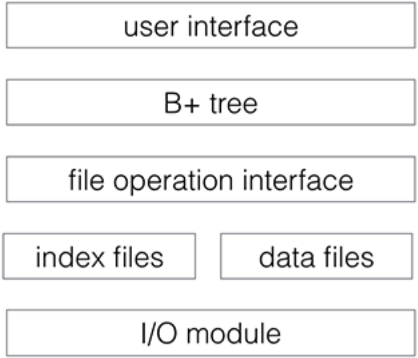


Figure 1: Architecture

Files

- index files (B+ tree)
- data files (keys or values, referenced in index files)
- consisted of a number of records

fixed-sized files

- header (file 0)
- file 1
- ...
- file n

Index

```
struct IndexRecord {
  union {
    BPlusNodeData data; // for non-empty record
    Location next; // for empty record
  };
};
```

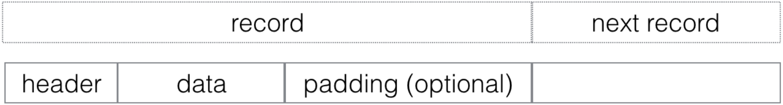
- Empty records stored as a linked list with head stored in the header
- Each non-empty records represents a node in B+ tree

B+ tree

- Order of B+ tree: 8
- Lazy deletion
- Root stored in the header of index files
- Each node contains locations of children or data

Data

```
struct DataRecord {
  int block_size; // size of this record
  union {
    int data_size; // for non-empty record, size of data
    Location next; // for empty record
  };
  void *getData() { return (void *)(&data_size + 1); }
};
```



record

next record

header

data

padding (optional)

Figure 2: Structure of Data Record

Data

Multiple linked lists containing empty records with different sizes

```
>= 32 bytes
>= 64 bytes
...
>= 8 MB
```

I/O Module

- encapsulate system APIs
- memory map on both Linux and Windows
- data synchronization maintained by system
- LRU algorithm to manage mapped files

Test

- Unit tests based on GoogleTest framework
- Use STL map as referenced

1. Randomly generate a number (more than one million) of keys and values and insert them into both map in STL and database in alphabetical order or arbitrary order.
2. Compare values of each key between map and database.
3. Delete all keys from database.
4. Check whether the keys have been deleted in database.

Benchmark

```
CPU:          2.9 GHz Intel Core i5
CPUCache:     3 MB
Memory:       16 GB
Disk:         APPLE SSD SM1024G
Keys:         16 bytes each
Values:       100 bytes each
```

Writes Performance

Insert nrec entries into an empty database

```
nrec   CPU Time (ns)  Iterations
--------------------------------------------
2              13808      57440  16.0239MB/s   141.452k items/s
8              59565      10000   14.858MB/s    131.16k items/s
64            387433       1858  18.2743MB/s   161.318k items/s
512          2654426        265  21.3382MB/s   188.365k items/s
4k          21391333         36  21.1826MB/s   186.992k items/s
32k        168748400          5  21.4817MB/s   189.631k items/s
256k      1440480000          1  20.1322MB/s   177.719k items/s
1024k     6437704000          1  18.0188MB/s   159.063k items/s
```

Writes Performance

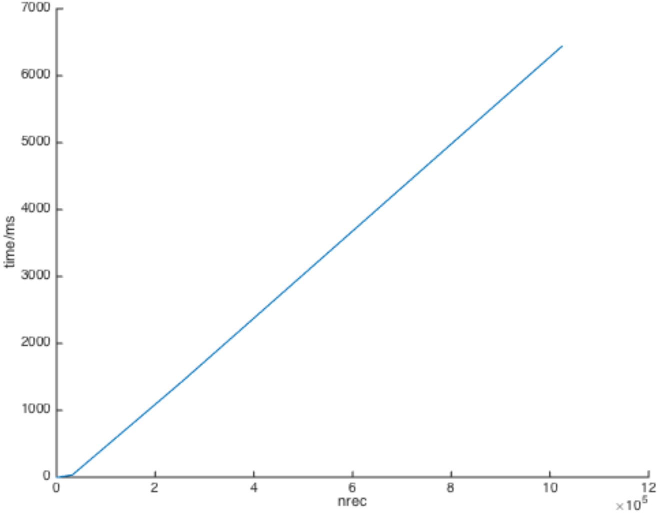


Figure 3: Write Performance

Reads Performance

Perform nrec read operations in a database with one million entries

```
nrec   CPU Time (ns)  Iterations
--------------------------------------------
2             13072     47620  16.9262MB/s   149.417k items/s
8             39985     17188  22.1336MB/s   195.386k items/s
64           305307      2310    23.19MB/s   204.712k items/s
512         2614599       302  21.6632MB/s   191.234k items/s
4k         18337323        31  24.7105MB/s   218.134k items/s
32k       148186400         5  24.4624MB/s   215.944k items/s
256k     1179927000         1  24.5778MB/s   216.963k items/s
1024k    4726068000         1  24.5447MB/s   216.671k items/s
```

Reads Performance

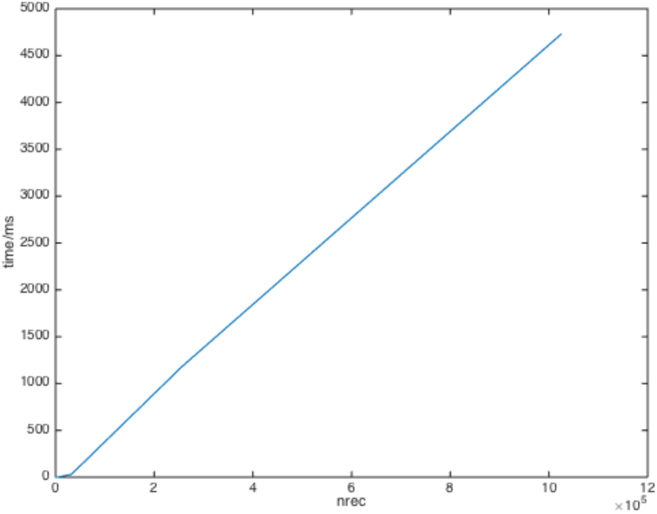


Figure 4: Read Performance

Mixed Operations Performance

1. insert NREC entries
2. fetch these entries
3. loop for 5 * NREC times:

   - randomly fetch an entry
   - randomly delete an entry, every 37 times
   - insert an entry and fetch it, every 11 times
   - randomly replace an entry, every 17 times

4. delete all entries; for each deletion, randomly fetch 10 records.

Mixed Operations Performance

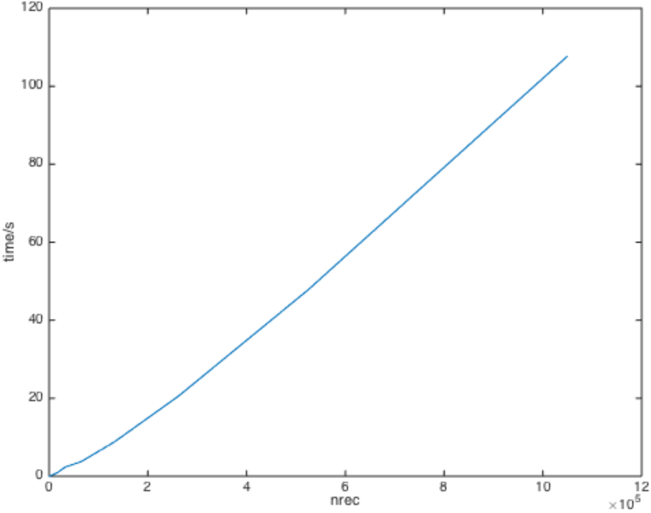


Figure 5: Performance of Mixed Operations